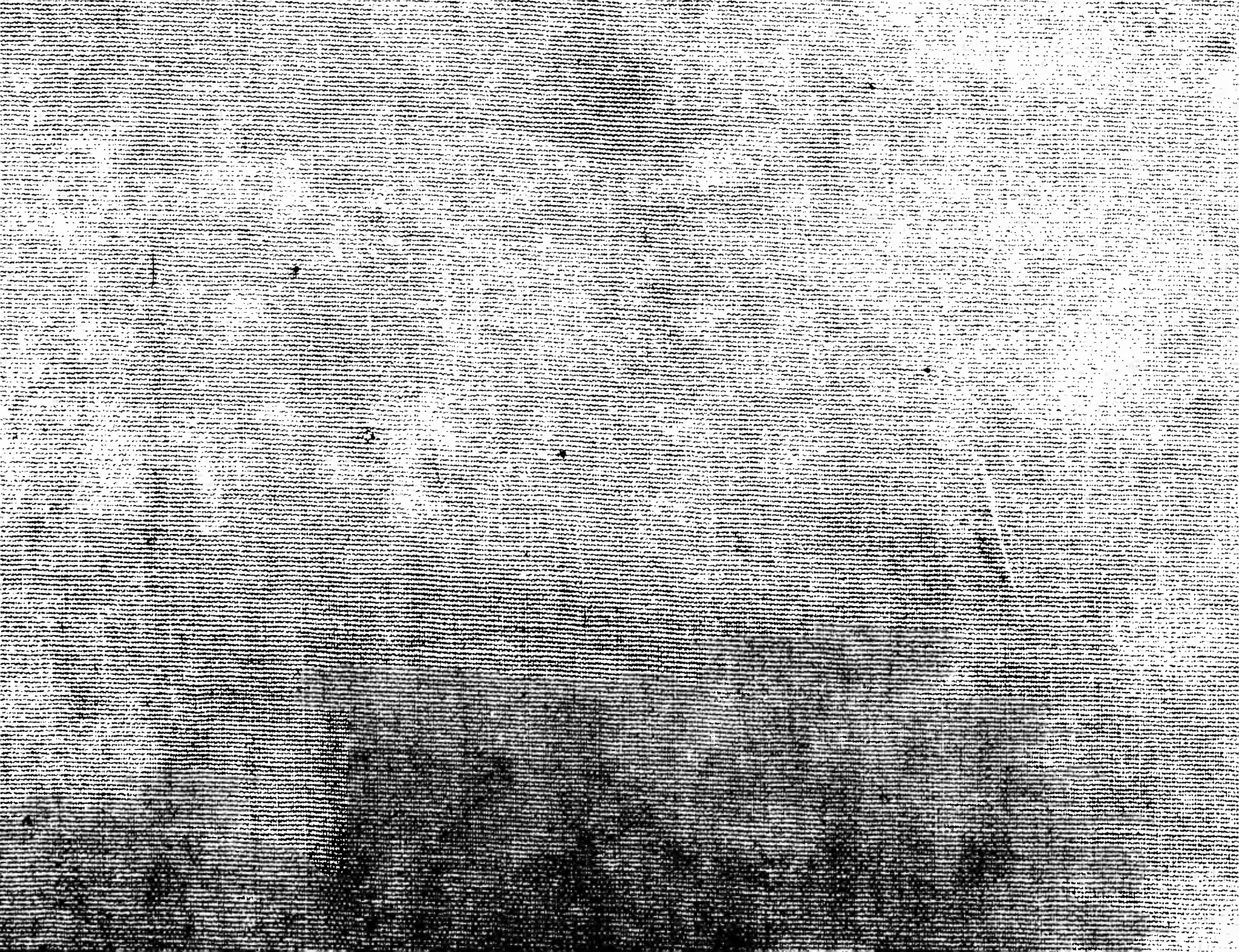

Memoirs of the Boston Society of Natural History.
Volume 7.

PHYLOGENY OF THE ECHINI,
WITH A REVISION OF PALAEOZOIC SPECIES.

BY ROBERT TRACY JACKSON.

WITH SEVENTY-SIX PLATES.

PLATES

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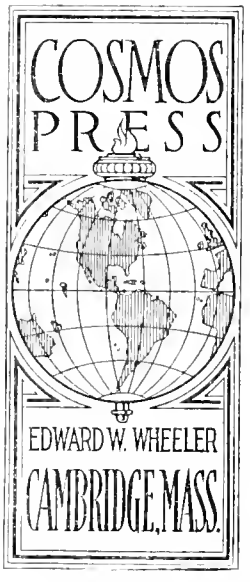


DESCRIPTION OF PLATES.

In the plates, the numbers designating figures are in heavy-faced italics, and in all cases they occur below the figures, usually on the left lower side. In order to see the full detail of the holotype photographic plates, also Plate 57, they should be examined with a reading glass. In most cases only a single page reference is given, which indicates the page on which the species is described. It is inexpedient usually to give references to the morphological or other parts of this memoir where the figures are discussed.

When the correct axes of a specimen are known, these are indicated by the Lovén method of enumeration, the ambulacra being numbered I, II, III, IV, and V, and the interambulacra 1, 2, 3, 4, and 5, the numbers revolving from left to right, or clockwise; when the specimen is viewed from below, Plate 2, fig. 1; when viewed from above, the numbers revolve counter-clockwise, Plate 2, fig. 3.

When the correct axes of a specimen are not known, as in most Palaeozoic Echini, the areas are lettered arbitrarily A, B, C, D, E, F, G, H, I, and J, the ambulacra being lettered B, D, F, H, and J. The lettering revolves from left to right when the specimen is viewed from above, and in external view, Plate 11, fig. 2; when viewed from below, the numbers revolve counter-clockwise, Plate 11, fig. 1 (p. 20).

It is important to bear in mind that when a specimen is viewed from the interior (an external mold is necessarily in internal view), the orientation and the lettering of ambulacral and interambulacral columns of plates are reversed from that seen from the exterior (p. 20), Plate 23, figs. 1 and 3 (compare Plate 55, figs. 1 and 2).

In the test as a whole, the lettering is as follows: *a*, *b*, the left and right columns of ambulacral plates in an area, Plate 31, fig. 1; or *a*, *a'*; *b'*, *b*, the two columns of demi-plates, *a*, *b*, and the two columns of occluded plates, *a'* *b'*, when there are four or more columns of ambulacral plates in an area, Plate 42, fig. 2, Plate 56, fig. 4.

The interambulacral columns in an area are numbered from 1 upward as they appear passing aborally in a given area, Plate 26; Plate 45, fig. 1. H, the heptagonal plate, associated with the initial pentagonal plate of a new column as introduced, is seen in many Palaeozoic Echini. Plate 45, fig. 1; *g*, genital plate; *oc*, ocular plate; and *sr*, suranal plate, Plate 1, figs. 1, 2, and 7. The letter X has no definite meaning, but is used to call attention to specific parts, Plate 25, figs. 1 and 2.

Lettering of the parts of the Aristotle's lantern with the associated muscles is as follows: *b*, brace; *c*, compass; *cap*, dental capsules; *con*., condyles of brace; *cr*., crests of the epiphyses, when such are developed; *e. b*., external brace muscles; *ep*., epiphyses; *fo. e*., and *fo. i*., external and internal foramina in the brace for articulation with the tubercles of the epiphyses; *gl*, glenoid cavity of an epiphysis, which receives the condyle of the brace; *i*, intercompass muscles; *i. b*., internal brace muscles; *ip*., interpyramidal muscles; *l. p*. left half of a pyramid; *pr*, protractor muscles of the lantern; *p. s*., pyramidal suture that divides the left and right half of a single pyramid; *r*, radial compass muscles; *re*., retractor muscles of the lantern; *r. p*., right half of a pyramid; *s*, suture, applied to different parts; *s. d*., dental slide that supports the tooth; *st*., styloid processes which are the dorsal extension of the dental slides in certain Echini; *t*, tooth; *tu. e*., and *tu. i*., external and internal tubercles of the epiphyses which interlock with corresponding foramina of the braces, Plate 2, figs. 7–17, and 19–21; Plate 5, figs. 1–12.

PLATE 1.

Bothriocidaris archaica sp. nov Page 239.

Fig. 1. Lyckholm Schicht, Ordovician, Hohenholm, Island of Dago, Russia. Height 12 mm., diam. 11.2 mm. Museum für Naturkunde, Berlin, holotype. ×3.8. Two columns of high hexagonal plates in each ambulacral area, pores superposed in a central peripodium. An ambulacral plate drawn in section under ambulacrum IV shows the surface outline and depth of the peripodial pit, also in dotted lines the supposed thickness of the plate and position of ambulacral pores. One column of hexagonal plates in each interambulacral area. The initial plate of each interambulacrum rests on the two plates of the second row of the peristome. (By an error in making my drawing in Berlin, the initial plate of interambulacrum 1 rests on the third instead of the second plate of ambulacrum 1*b*.) The youngest interambulacral plates dorsally have no tubercles, other interambulacral plates have one to three tubercles each (excepting the second plate in area 2 where it was probably worn off); the greatest number of tubercles is near the mid-zone. In one ambulacral plate tubercles were drawn in from an adjacent plate, otherwise the tubercles of all plates are as observed. There is no resorption of the base of the corona. There are two rows of ambulacral plates on the peristome and of these, the primordial ambulacral plates 1*a*, II*a*, III*b*, IV*a*, V*b* are larger, thus orienting the specimen by Lovén's law. (See text-figs. 2, p. 54; 22, p. 70; 40, p. 80.)

Fig. 2. Same specimen. ×5.1. Dorsal view. Oculars large, forming a continuous ring adorally, covering the ambulacra and interambulacra completely; genitals small, in the dorsal angles of the oculars (pp. 42, 87). There are about nine periproctal plates. (See text-fig. 162, p. 149.)

Bothriocidaris pahleni Schmidt. Page 242.

Fig. 3. Jeweschen Schicht, Ordovician, near Nommis, Esthland, Russia. Height 16 mm., diam. 15.5 mm. Esthländischen Provinzial Museum, Reval (after Schmidt, 1874, Plate 4, fig. 1a). Holotype, ×, about 1.6. Spines and tubercles on ambulacral, but wanting on interambulacral plates. (Compare photograph, Plate 8, fig. 1.)

Fig. 4. Same specimen (after Schmidt, Plate 4, fig. 1c). ×, about 4. Ambulacral pores superposed in a central peripodium, tubercles perforate, on ambulacral plates only.

Fig. 5. Same specimen (after Schmidt, 1874, Plate 4, fig. 1d) much enlarged. Two primordial ambulacral plates with a (tooth?).

Fig. 6. Same specimen (after Schmidt, 1874, Plate 4, fig. 1b) enlarged. Dorsal view. Genitals 1 and 4 are dorsal to the oculars, but genitals 2 and 3 separate the oculars and reach the interambulacra (p. 87).

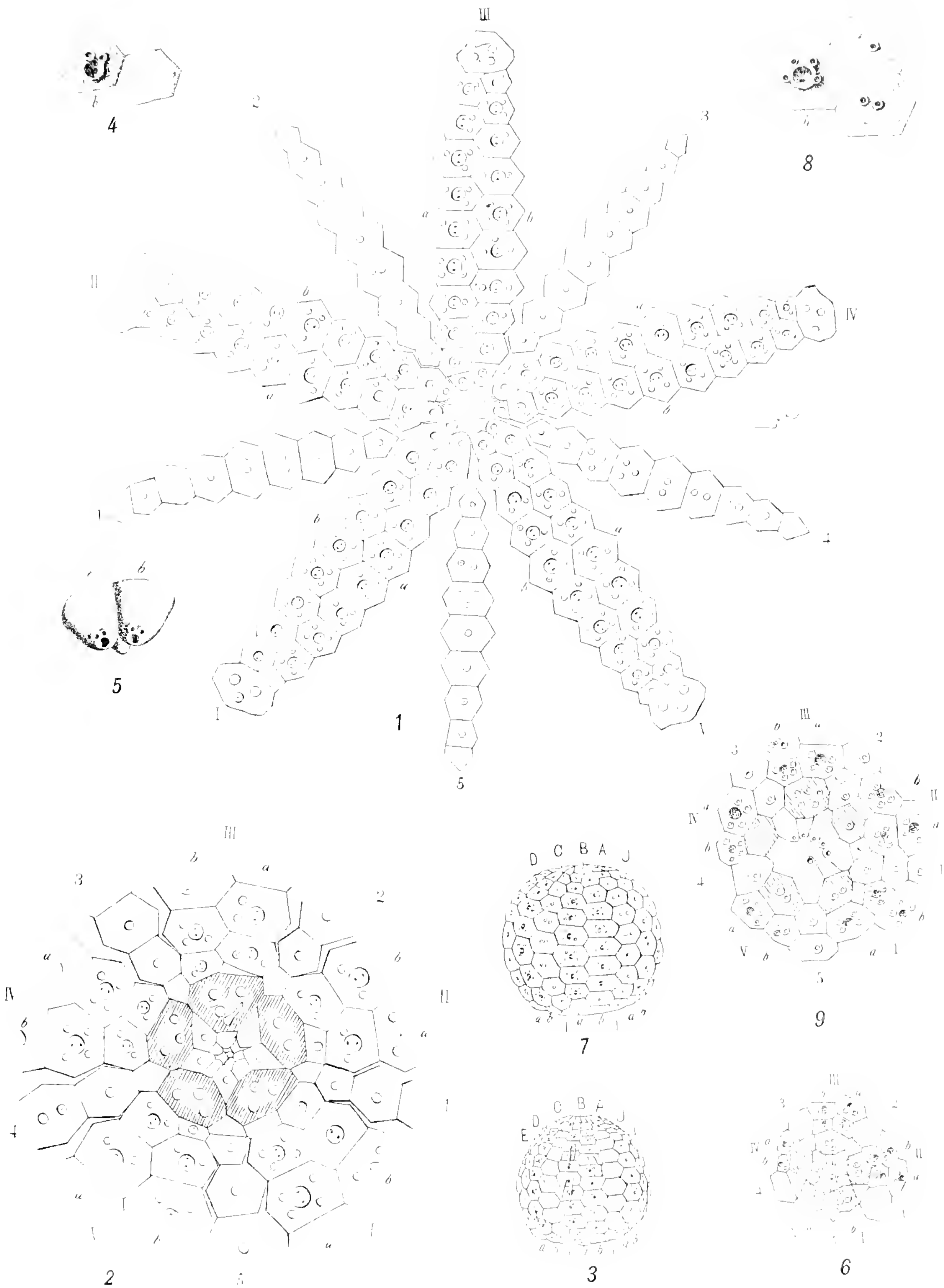
Bothriocidaris globulus Eichwald. Page 243.

Fig. 7. Lyckholm Schicht, Ordovician, Hohenholm, Island of Dago, Russia. Height 18 mm., diam., 18.5 mm. (after Schmidt, 1874, Plate 4, fig. 2a). ×, about 1.6. Perforate tubercles on both ambulacral and interambulacral plates.

Fig. 8. Same specimen (after Schmidt, 1874, Plate 4, fig. 2d). ×, about 4. Ambulacral plate with pores superposed and perforate tubercles which also occur on interambulacral plates.

Fig. 9. Same specimen (after Schmidt, 1874, Plate 4, fig. 2b), enlarged. Dorsal view. Genitals all separate the oculars and reach the interambulacral areas (p. 87).

Figs. 1, 2 redrawn by J. Henry Blake from my drawings; Figs. 3–9 copied by W. M. Barrows. The lettering and orientation of all figures are mine.



Henry Blake & M. Barrows del.

Heliotype Co. Boston

PLATE 2.

Goniocidaris canaliculata A. Agassiz.

Figs. 1–3. Falkland Islands. Very young, diam. 1.45 mm. (after Lovén, 1892, Plate 2, figs. 7–9). × about 26.

Fig. 1. Ventral view, primordial ambulacral plates only on the peristome, primordial interambulacral plates in basicoronal row, succeeded in the next row by two plates in each area. (Compare text-figs. 23, p. 70; 45, p. 80.) Page 65.

Fig. 2. Same specimen, side view. Ambulacral plates high hexagonal, pores superposed in each plate. (Compare text-fig. 3, p. 54.) Page 58.

Fig. 3. Same specimen, dorsal view. Ocular exsert, no genital, but one large madreporic pore. One plate fills the periproct (possibly this single plate is an error, p. 174). (Compare adults, text-figs. 73, 74, p. 99.) Pages 101, 172.

Fig. 4. Southern part of South America. Diam. 23 mm. R. T. J. Coll., 745. × 11. Ambulacral plates at mid-zone low, wide; in young plates beneath the ocular, the height equals the width, as at mid-zone in a young individual, fig. 2. Same specimen as text-fig. 74, p. 99. Page 58.

Eucidaris tribuloides (Lamarck).

Fig. 5. Florida. Diam. 5 mm. R. T. J. Coll., 645. × 17. Young ambulacral plates in the placogenous zone are high hexagonal. Page 58.

Fig. 6. Florida. Diam. 5 mm. R. T. J. Coll., 644. × 21. On the peristome are four or five high, hexagonal ambulacral plates in each column. In the primordial ambulacral row the I*a*, II*a*, III*b*, IV*a*, V*b* are larger than the I*b*, II*b*, III*a*, IV*b*, V*a*. Two plates in each interradial area of peristome. (Compare adult, text-fig. 46, p. 80.) Page 82.

Figs. 7–16. Nassau, Bahamas. R. T. J. Coll., 694. Study of the Aristotle's lantern. Page 182.

Fig. 7. Side view of pyramid. × 2.6. The pyramid has ridges for attachment of interpyramidal muscle; epiphysis has a glenoid cavity, *gl.*, and external and internal tubercles, *tu. e.*, *tu. i.*, for interlocking with brace; tooth grooved.

Fig. 8. Pyramid, face view. × 2.6. Foramen magnum very shallow; the tooth, epiphyses, braces, and compasses are in place (compare text-fig. 210, p. 184.)

Fig. 9. Lantern, top view. × 2.6. In area I all parts are in place; in V the compass is removed; in IV the compass and brace are removed and in area II the epiphyses also are removed to show the smooth upper face of the pyramids. (Compare text-fig. 218, p. 191.)

Fig 10. Half-pyramid, inner view. × 2.6. The pyramidal suture extends nearly to the top, the dental slide reaches only part way to base of foramen magnum as in the Perischoechinoida.

Fig. 11. Pyramid. × 2.6. Face view, with epiphyses removed.

Fig. 12. Compass. × 5.3. Top and side views, separated on the line of the suture.

Fig. 13. Brace. × 5.4. Top view.

Fig. 14. Left epiphyses of area 2, fig. 9. × 5.4. Top view, to show glenoid cavity, *gl.*, and external and internal tubercles, *tu. e.*, *tu. i.*, for interlocking with the brace.

Fig 15. Brace. × 5.4. Lower view, showing condyles, *con.*, and external and internal foramina, *fo. e.*, *fo. i.*, which interlock with the glenoid cavity and tubercles of the epiphyses.

Fig. 16. Right epiphysis of area 4, fig. 9. × 5.2. Lower view. X in both figures shows the face of sutural contact.

Goniocidaris canaliculata A. Agassiz.

Fig. 17. Falkland Islands. Very young (after Lovén, 1892, Plate 3, fig. 23). Much enlarged. Lantern inclined, foramen magnum deep, interpyramidal muscles long, as in the Perischoechinoida. (See text-fig. 209, p. 184.) Page 181.

Phyllacanthus thomasii A. Agassiz and Clark.

Fig. 18. Hawaiian Islands. Diam. 65 mm. Adapted from A. Agassiz and Clark, 1907, Plate 27. × 1.7. More than one column of non-ambulacral plates in each interradial area of the peristome. Page 82.

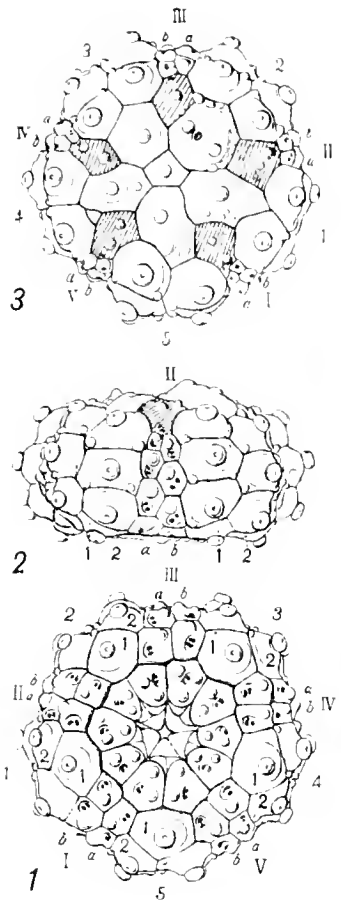
Phormosoma placenta Wyville Thomson.

Figs. 19–21. Lat. 40° 53′ 30″ N. Lat., 66° 21′ 00″ W. Long. Albatross Station 2530, 956 fathoms. R. T. J. Coll., 778. Study of lantern. Page 185.

Fig. 19. Face view. × 3.2. Pyramids wide-angled, with deep rounded foramen magnum, long interpyramidal muscles, compasses very long. Teeth are grooved and styloid processes extend above the base of foramen magnum as they do in other Centrechinoida and as they do not in the Cidaroida and Perischoechinoida.

Fig. 20. Dorsal view. × 3.4. Lantern inclined, teeth grooved; in area I the tooth is removed to show dental slides; in area V all parts are in place; in area I the compass is removed; in area IV the compass and brace are removed to show the epiphyses; and in area II the epiphyses also are removed to show the top of half-pyramids with the characteristic pits. (Compare Plate 27, figs. 4–6.)

Fig. 21. Pyramid, side view. × 3.5. Showing the tooth, ridges for attachment of interpyramidal muscle, and epiphysis with glenoid cavity.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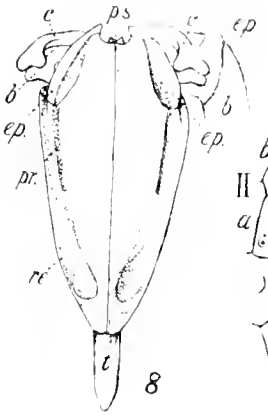
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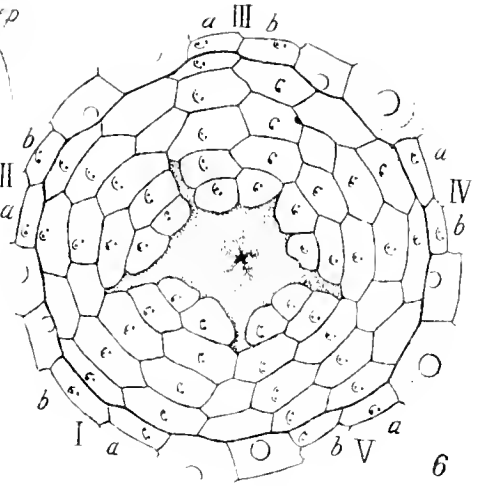
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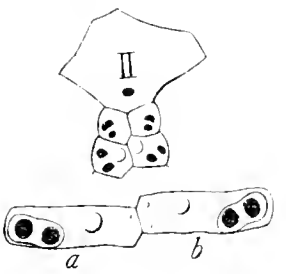
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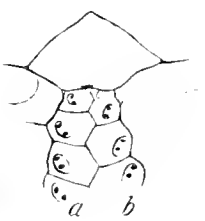
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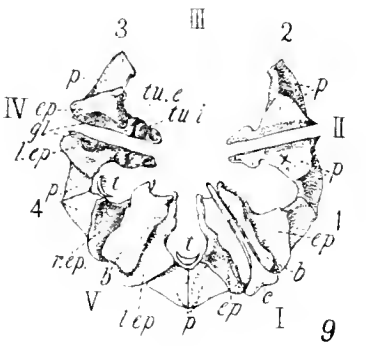
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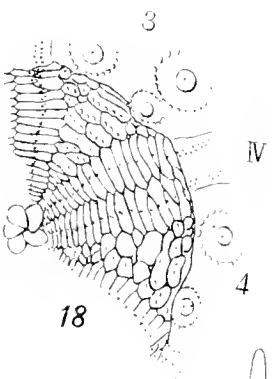
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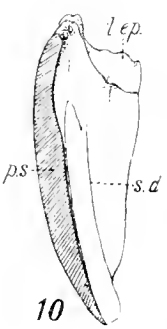
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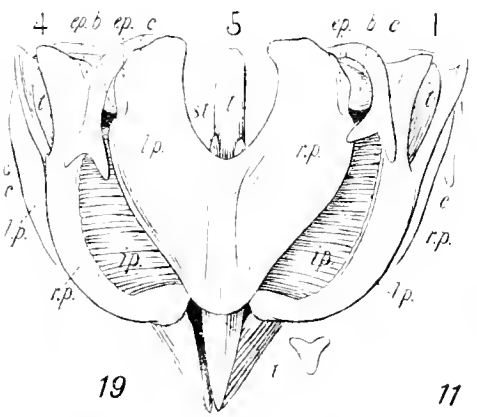
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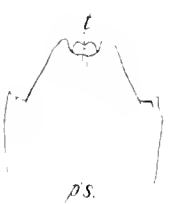
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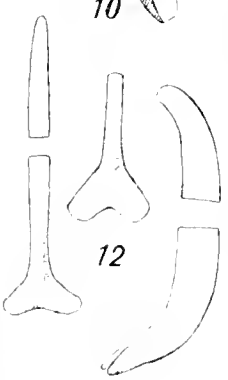
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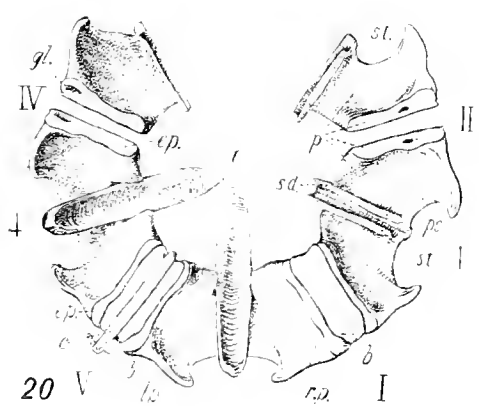
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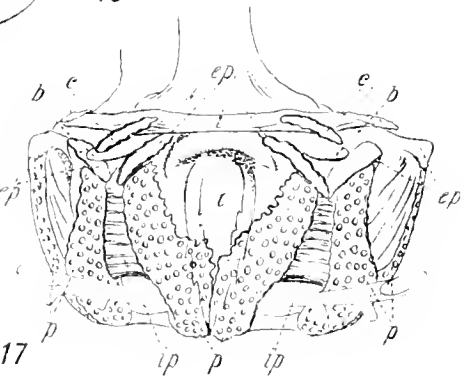
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PLATE 3.

Eucidaris tribuloides (Lamarck).

Fig. 1. Nassau, Bahamas. Diam. 48 mm. R. T. J. Coll., 741. × 7. Young plate from placogenous zone with developing spine. In lower figure the plate is seen in side view and the spine is removed showing a low imperforate tubercle. The spine is low, concave, saucer-shaped, as seen from the side and partially from lower view; the upper figure is the same plate in face view with spine removed. Page 77.

Fig. 2. Same specimen. × 7. The same plate in side view with the spine in place. Page 77.

Phyllacanthus baculosa (Lamarck).

Fig. 3. Mauritius. Diam. 44 mm. R. T. J. Coll., 752. × 2. Ocular V, I, IV insert, an arrested variant. (Compare text-fig. 169, p. 149.) Page 102.

Fig. 4. Mauritius. Diam. 41 mm. R. T. J. Coll., 753. × 2. Ocular V, I, IV, II insert, III exsert, an arrested variant. Page 102.

Echinus microtuberculatus Blainville.

Fig. 5. × about 160 (after Bury, 1895, Plate 7, fig. 34). *oc.*, large oculars each with a four-pronged spine, and huge tentacle, *ten.*; *g*, small genitals; *a*, *b*, two ambulacral plates each with a six-pronged spine below the ocular; *i*, primordial interambulacral plates each with a six-pronged spine. Pages 65, 87.

Hypsiechinus coronatus Mortensen.

Fig. 6. Very young (after Mortensen, 1903, Plate 7, fig. 6). Highly magnified. *Oc.*, ocular plates; *a*, *b*, young ambulacral plates of the corona; *i*, primordial interambulacral plates; *P. A.*, primordial ambulacral plates; *t*, teeth. Page 65.

Schematic young echinoid.

Fig. 7. Specimen in the protechinus stage. *g*, small genitals; *oc.*, large oculars; *a*, *b*, young ambulacral plates of the corona; *i*, young primordial interambulacral plates; *P. A.*, primordial ambulacral plates; *t*, teeth. Pages 53, 90.

Phormosoma placenta Wyville Thomson.

Fig. 8. Young specimen. Diam. 3 mm. (after Mortensen, 1907, p. 24). Highly magnified. The genitals meet in a ring, and as a consequence, the oculars must be exsert. (Compare adult, text-fig. 170, p. 149.) Page 110.

Fig. 9. Young specimen. Diam. 3 mm. (adapted from Mortensen, 1904, p. 54). Highly magnified. Only one row of primordial ambulacral plates on the peristome; the primordial interambulacral plates are in the basicoronal row. (Compare adult, text-fig. 13, p. 80.) Page 79.

Fig. 10. Off Nevis, West Indies, 375 fathoms. Diam. 7 mm. (after A. Agassiz, 1904, Plate 43, fig. 1). Two rows of ambulacral plates on the peristome. (Compare Bothriocidaris, Plate 1, fig. 1; also text-figs. 41, 13, p. 80.) Page 79.

Strongylocentrotus dröbachiensis (O. F. Müller).

Fig. 11. Very young specimen. Diam. 1.2 mm. (after Lovén, 1892, Plate 4, fig. 25). × about 50. Lantern inclined, interpyramidal muscles long, ten primordial ambulacral plates only on the peristome, primordial interambulacral plates in basicoronal row, ambulacral plates of corona high, simple. (Compare text-figs. 49, 50, p. 80.) Page 65.

Phyllacanthus baculosa (Lamarck).

Fig. 12. Mauritius. Diam. 45 mm. R. T. J. Coll., 901. Ambulacrum II, showing spinules on the interior of ambulacral plates; e, from the ambitus, × 5.5, a single spinule over each inner pore; d, enlargement of same, × 10.3; b, from the base of the corona, × 5.5; another set of blunter spinules appears between the pores and the middle of the area. (Compare Plate 24, fig. 6.) Ventrally, these inner spinules are fused into a continuous ridge (compare text-fig. 224, p. 193). a, enlargement of two plates, × 10.3, showing the two sets of spinules. Page 61.

Eucidaris tribuloides (Lamarck).

Fig. 13. Jamaica. Diam. 43 mm. R. T. J. Coll. Ambulacrum II, showing spinules on the interior of ambulacral plates. × 5.3, and one plate, × 10.6. There are three spinules over the inner pore of each plate. Page 61.

Echinus magellanicus Philippi.

Fig. 14. Patagonia. Diam. 3 mm. R. T. J. Coll., 894. × 19. Oculars all exsert, no genital pores exist, and only one madreporic pore; the suranal plate fills the periproct. (Compare adult, text-fig. 165, p. 149.) Pages 119, 176.

Collyrites acuta Desor.

Fig. 15. After Lovén, 1874, Plate 6, fig. 55. In the basicoronal row there are ten primordial ambulacral plates: the *Ia*, *IIa*, *IIIb*, *IVa*, *Vb* are larger each with two pairs of pores, the *Ib*, *IIb*, *IIIa*, *IVb*, *Va* are smaller each with one pair of pores also five primordial interambulacral plates are in the basicoronal row, succeeded in the second row by two plates in each area. Page 56.

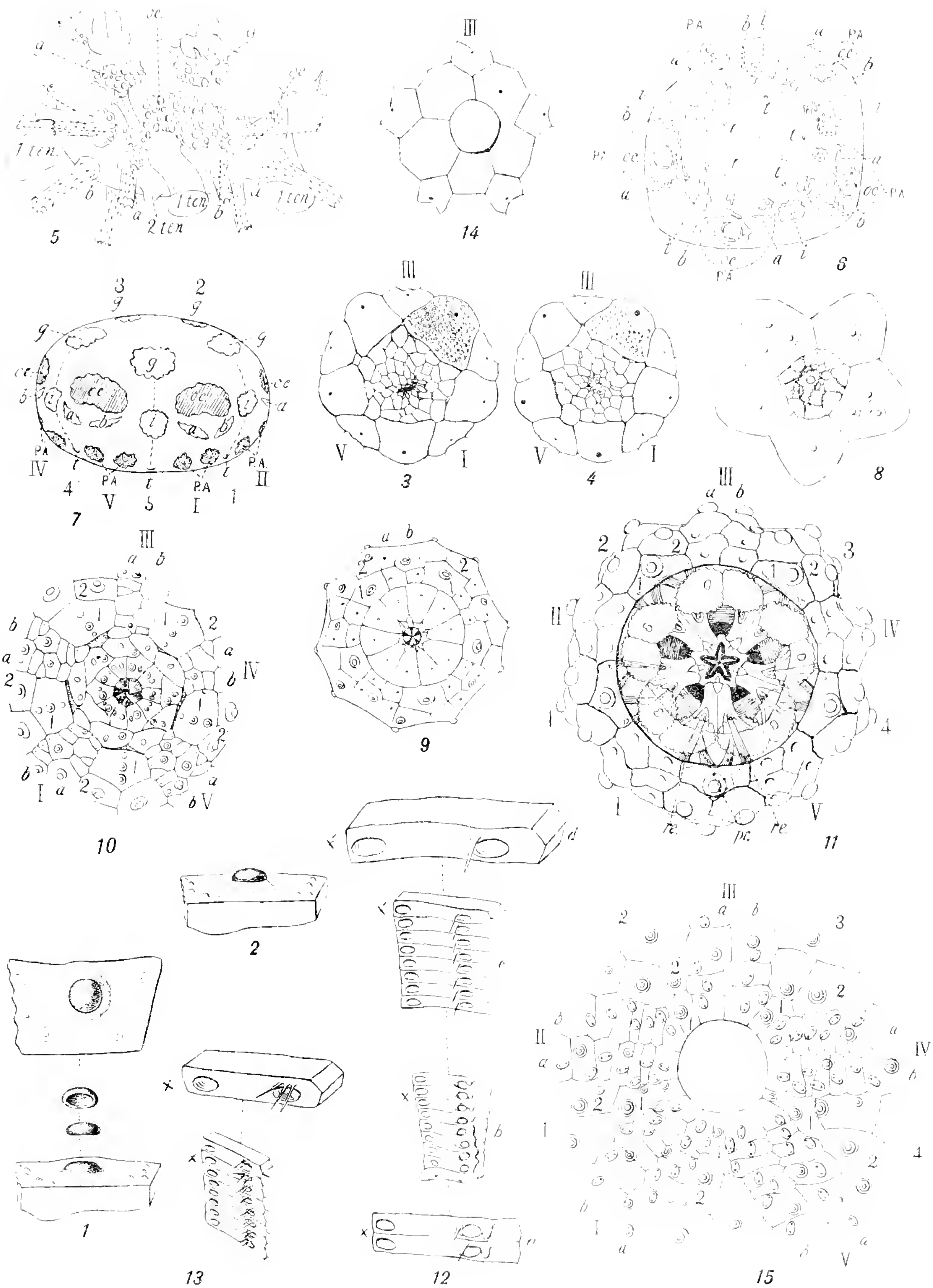
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PLATE 4.

Salenia pattersoni A. Agassiz.

Figs. 1–5. Off Havana, Cuba, 300 fathoms. Diam. 12 mm. R. T. J. Coll., 669. All drawn from a single specimen.

Fig. 1. Apical disc seen from the exterior. × 6. Ocular I is insert, all others exsert; ocular and genital pores invisible; few madreporic pores in genital 2; suranal plate is opposite genital 3. Pages 112, 172.

Fig. 2. Apical disc seen from the interior. × 6. Pores are visible in all ocular and genital plates; only one madreporic opening in genital 2, though there are several pores on the exterior of the same plate, fig. 1. Page 172.

Fig. 3. Segment of lantern, showing a keeled tooth, foramen magnum deep and open above, narrow epiphyses, brace and compass. × 12. (Compare text-fig. 212, p. 184.) Page 186.

Fig. 4. The lantern with muscles and perignathic girdle seen from above. × 12. In area IV all parts of the lantern are in place; in V the compass is removed; in I the brace is removed and also the epiphysis of one side, showing therefore in this area on one side an epiphysis, and on the other side the top of the pyramid with its pits. Protractor, *pr.*, and radial compass muscles, *r*, are inserted on low apophyses; retractors are inserted on styloid auricles. (Compare fig. 5.) Pages 186, 195.

Fig. 5. To show the perignathic girdle and attachment of lantern muscles to the same. × 12. Protractor and radial compass muscles are inserted on the low apophyses, *ap.*, retractors on the styloid auricles, *au.* Page 195.

Salenocidaris varispina A. Agassiz.

Fig. 6. Lesser Antilles, 687 fathoms. Diam. 7 mm. R. T. J. Coll., 668. × 12. Ocular I insert, others all exsert. Ocular and genital pores visible; suranal plate opposite genital 3. Pages 112, 174.

Peltastes wrighti Desor.

Fig. 7. Greensand, Cretaceous, Farringdon, England. Diam. 12.5 mm. R. T. J. Coll., 674. × 4. All oculars exsert; the suranal plate is opposite ocular III. Pages 111, 174.

Stomopneustes variolaris (Lamarck).

Fig. 8. Ceylon. R. T. J. Coll., 852. × 3. Segment of the lantern; tooth keeled, foramen magnum deep, epiphyses narrow, not meeting in suture; dorsally the half-pyramids extend over the foramen and produce spurs which support the tooth. Page 186.

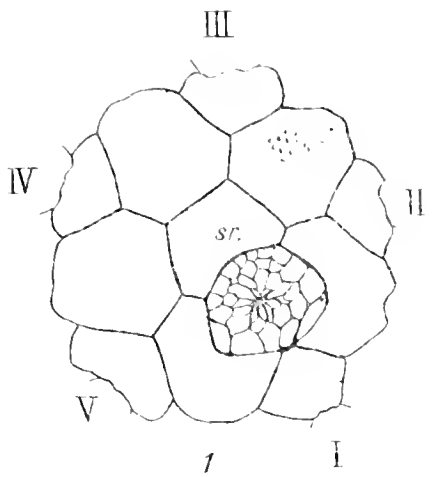
Fig. 9. Same specimen. × 3. Dorsal portion of a half-pyramid to show spur of the same that supports the tooth; epiphysis removed. Page 186.

Fig. 10. Another specimen, same locality. R. T. J. Coll., 868. × 4. Dorsal view of a pyramid, on one side with epiphysis in place, on the other side the epiphysis is removed to show pits in the pyramid, which dorsally by its spurs gives support to the tooth. Page 186.

Arbacia punctulata (Lamarck).

Fig. 11. Woods Hole, Massachusetts. Diam. 33 mm. R. T. J. Coll., 685. × 3. Interambulacrum 4 has only one column of plates dorsally, genital 4 is absent, oculars IV and V are in contact and cover entirely areas IV, 4, and V. (Compare Bothriocidaris, Plate 1, fig. 2; Tripneustes, Plate 6, fig. 1.) Pages 45, 88.

Fig. 12. Florida. R. T. J. Coll., 889. × 3. Genital 4 is wanting, therefore oculars IV, V are in contact and cover ambulacra IV, V, and interambulacrum 4 completely. There are two columns of plates in interambulacrum 4 as usual. (Compare fig. 11 and text-fig. 185, p. 167.) Page 46.



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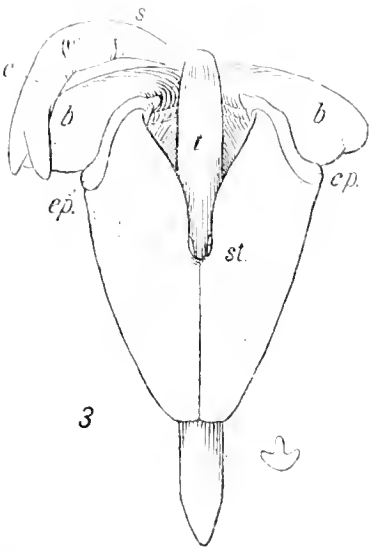

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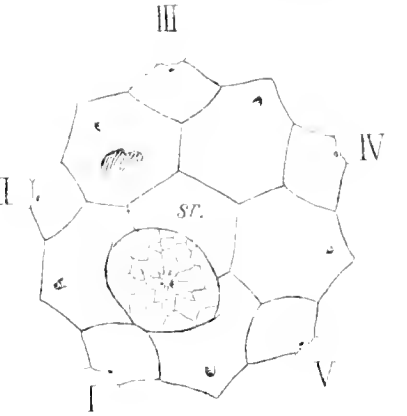

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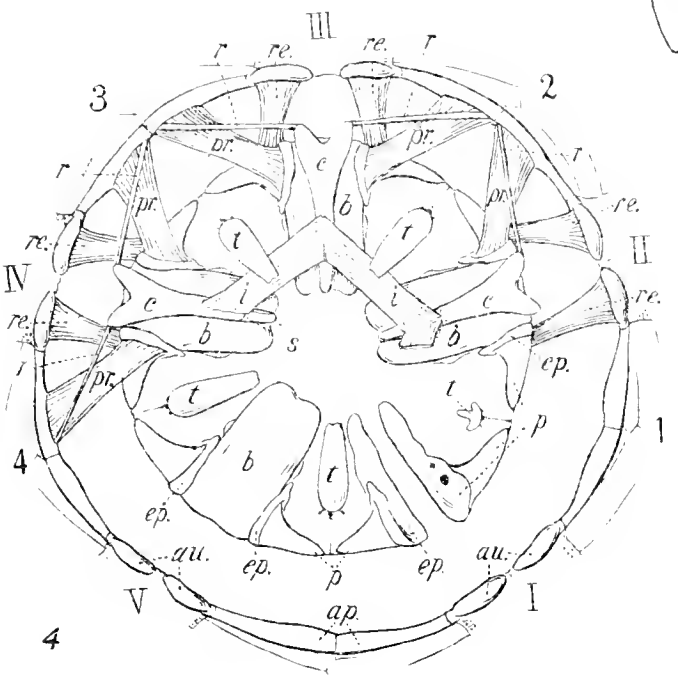

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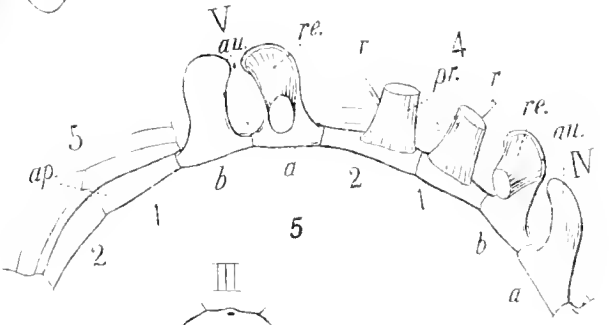

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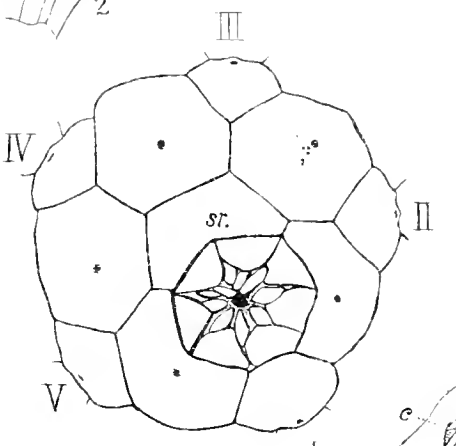

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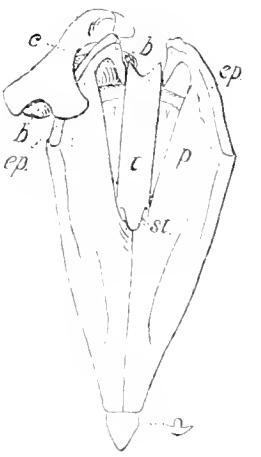

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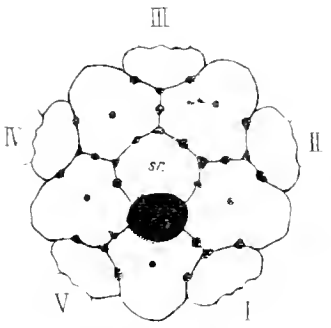

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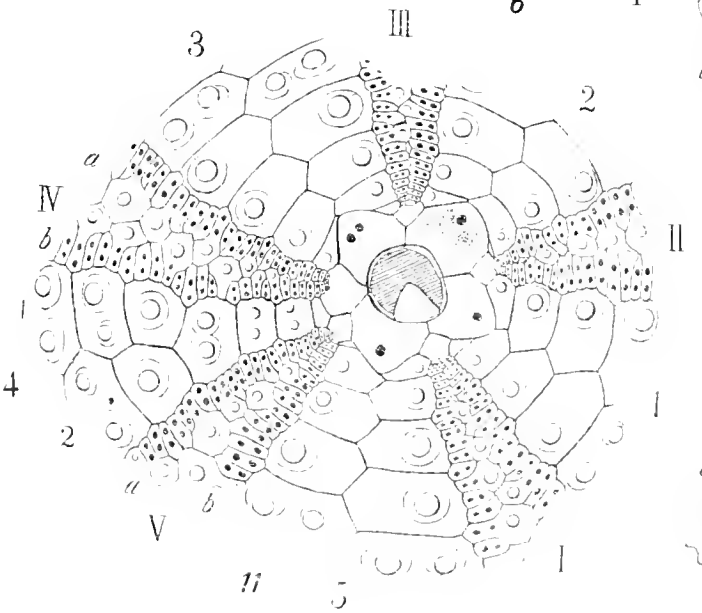

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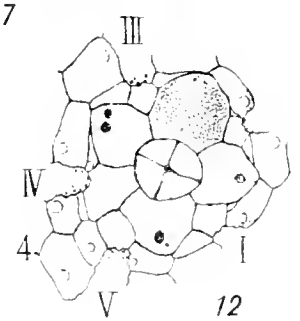

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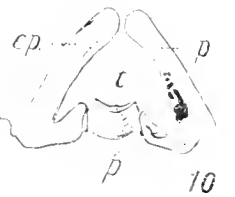

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PLATE 5.

Strongylocentrotus dröbachiensis (O. F. Muller).

Figs. 1-12. Mt. Desert, Maine. Studies of the lantern and muscles of the same. Page 178.

Fig. 1. Lantern with muscles and perignathic girdle. × 4. Dental capsules, *cap.*, very large; intercompass muscles, *i*, pass beneath the dental capsules; protractor, *pr.*, and radial compass muscles, *r*, are inserted on low apophyses; retractor muscles, *re.*, are inserted on auricles. (Compare text-fig. 229, p. 193.)

Fig. 2. The lantern, facing pyramid 5, showing interpyramidal muscles, styloid processes of the dental slides, epiphyses, crests, and compasses. × 4. (Compare text-fig. 213, p. 184.)

Fig. 3. Pyramid of interradius 4 in side view, with corrugations for the attachment of interpyramidal muscles, epiphysis with its glenoid cavity, crest, external and internal tubercles. × 4.

Fig. 4. A pyramid, showing the origin of the protractor and retractor muscles on the pyramid and epiphysis, left epiphysis removed. The pyramidal suture, *p. s.*, styloid processes, *st.* of the dental slides are visible above the base of the deep foramen. × 4.

Fig. 5. Pyramid of interradius 4 seen from the center, showing dental slides, corrugations for muscle attachment, and the epiphyses with their glenoid cavities, external and internal tubercles and crests. × 4.

Fig. 6. Left half-pyramid, the right half being removed, showing tooth and dental capsule in place; also, epiphysis, *ep.*; brace, *b*; and intercompass muscle, *i*; the pyramidal sutural face, *p. s.*, is shaded. × 4.

Fig. 7. Upper part of pyramid, with dental capsule in place; styloid processes are prominent. × 4.

Fig. 8. Tooth flattened out. × 4. At the basal growing portion, which lies in the dental capsule, the tooth is grooved, as is the whole tooth in the Cidaridae and other primitive types. Lower down a keel develops, as shown by sections at the points indicated.

Fig. 9. Top of lantern to show the structure. × 4. At areas 2, 3, a whole tooth is in place; at 1, the pulpy part of the tooth is removed; at 4 and 5 the tooth is removed. At area III the compass, brace, and epiphyses are in place; at V, the compass is removed; at IV the brace also is removed to show the epiphyses; and at I the epiphysis of one side is removed to show the pits in the top of the pyramid.

Fig. 10. A pyramid of interradius 5 seen from above. × 4. The epiphyses are removed to show the top of the pyramid with its characteristic pits.

Fig. 11. A brace, seen from below. × 4.

Fig. 12. Epiphyses with brace in place to show internal and external brace muscles, *e. b.*, *i. b.* × 5.

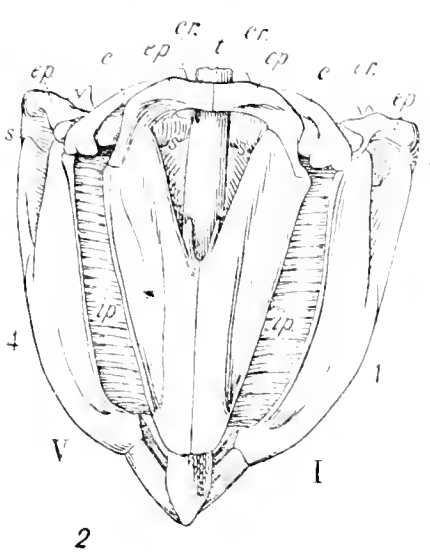
Fig. 13. Massachusetts Bay. Diam. 52 mm. R. T. J. Coll., 657. × 3. Madreporic pores are in genitals 2 and 3; oculars I, V insert. Page 172.

Fig. 14. York, Maine. Diam. 46 mm. R. T. J. Coll., 779. × 3. Madreporic pores are in genitals 1, 2, 3, and oculars II and III. Page 173.

Fig. 15. York Harbor, Maine. Diam. 47 mm. × 3.6. Oculars I, V insert; an interspace exists between genital 5 and ocular I where the periproct reaches interambulacrum 5 as in some Echinothuriidae, a very rare variant. (Compare text-fig. 170, p. 149.) Pages 63, 177.

Fig. 16. Calderwood Island, Fox Island Thoroughfare, Maine. Diam. 36 mm. R. T. J. Coll., 822. × 3.7. Partially tetramerous; interambulacrum 1 is wanting, so that ambulacra I, II are in contact throughout. There are five oculars, V only insert, and five genitals, but genital 1 is imperforate and lies dorsal to oculars I, II, a very rare variation. (Compare Plate 1, fig. 2.) Pages 12, 167.

Lettering: *b*, brace; *c*, compass; *cr.*, crests of the epiphyses; *e. b.*, and *i. b.*, external and internal brace muscles, extending from the braces to the epiphyses; *ep.*, epiphyses; *gl.*, glenoid cavity; *i*, intercompass muscles; *ip.*, interpyramidal muscles; *l. p.*, left half-pyramid; *p*, pyramid; *pr.*, protractor muscles; *p. s.*, pyramidal suture; *r*, radial compass muscles; *re.*, retractor muscles; *r. p.*, right half-pyramid; *st.*, styloid process of the dental slide; *t*, tooth; *tu. e.* and *tu. i.*, external and internal tubercles by which the epiphyses interlock with the brace.



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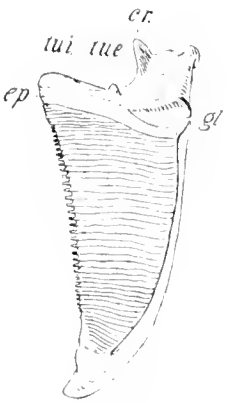

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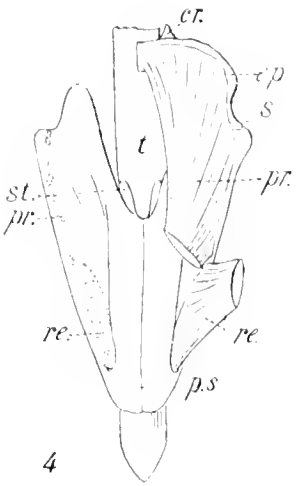

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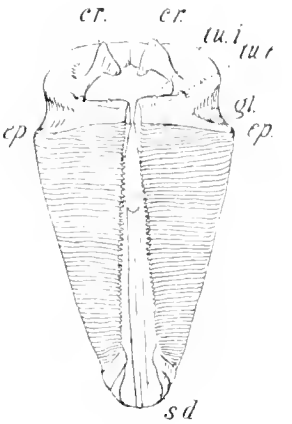

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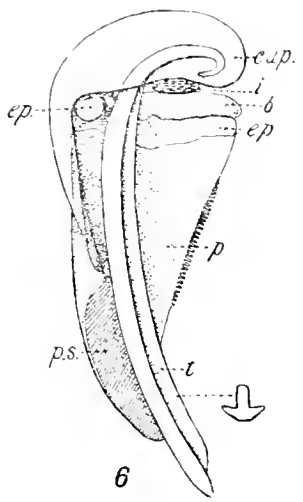

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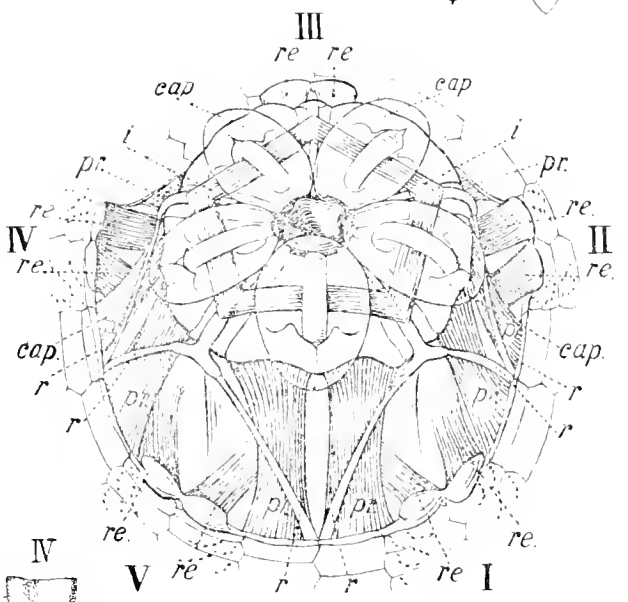

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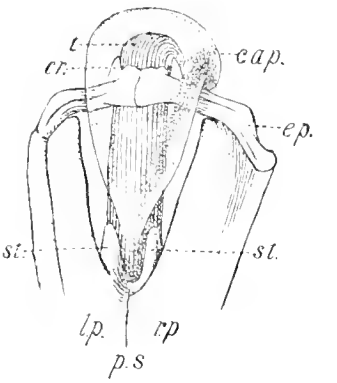

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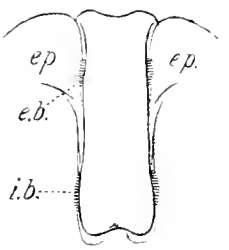

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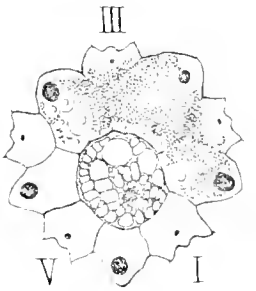

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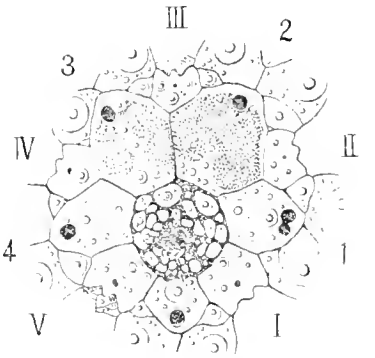

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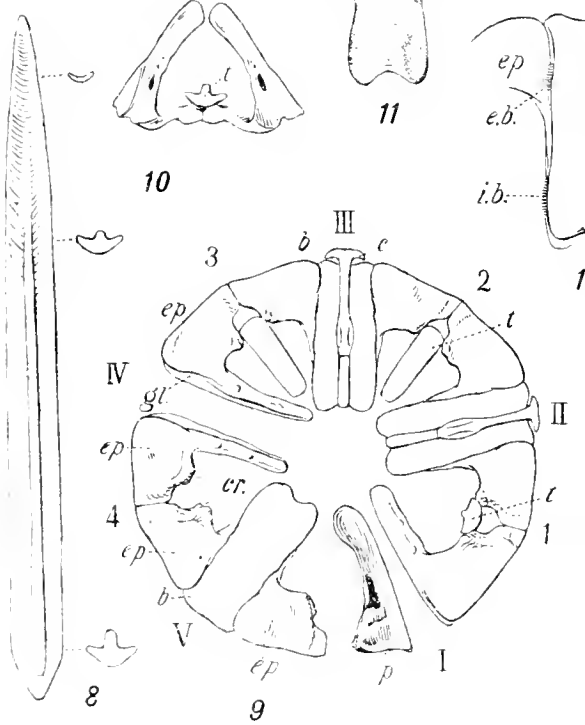

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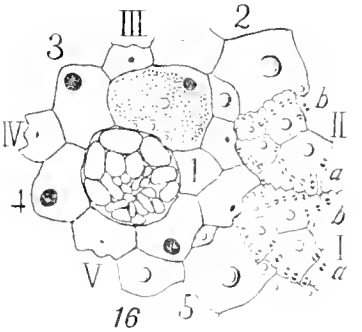

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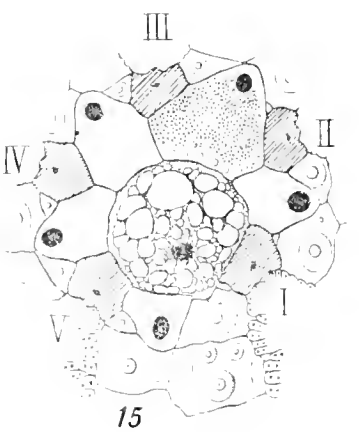

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HENRY BLAKE DEL. HELIOTYPE CO. BOSTON

PLATE 6.

Arbacia punctulata (Lamarck).

Fig. 1. Woods Hole, Massachusetts. Diam. 30 mm. R. T. J. Coll., 660. × 4. Almost completely tetramerous. There are four teeth, ambulacra, interambulacra, and oculars, but five genitals. The absent parts are: ocular and ambulacrum II, the right half of interambulacrum 1 and the left half of interambulacrum 2. From this structural deficiency the right half of interambulacrum 2, which is related to ocular III, and the left half of interambulacrum 1, which is related to ocular I, come together and are in contact throughout their length. Same specimen as photograph, Plate 8, fig. 2. Page 39.

Tripneustes esculentus (Leske).

Fig. 2. Pernambuco, Brazil. Diam. 110 mm. R. T. J. Coll., 739. × 1.9. Completely hexamerous; six teeth, ambulacra, interambulacra, oculars, and genitals, but genitals 3 and 6 are fused. The added parts lie between oculars III and IV. (Compare Plate 7, fig. 7.) Page 46.

Fig. 3. The same specimen from the mid-zone showing an ambulacral area of the usual width and an interambulacrum narrower than is normal. × about 0.9. Pages 46, 78.

Fig. 4. Jamaica. Diam. 75 mm. R. T. J. Coll., 806. × 2.8. Partially hexamerous. Ocular and ambulacrum VI lie between ambulacrum II and interambulacrum 2. Interambulacrum 6 consists of a single column of plates that abuts against oculars II and VI (compare Bothriocidaris Plate 1, fig. 2). Oculars I, V, IV are insert and genital 3 is split by a horizontal suture (compare text-fig. 190, p. 169). Page 48.

Strongylocentrotus lividus (Lamarck).

Fig. 5. Naples Station. Diam. 61 mm. R. T. J. Coll., 696. × 2.8. Highly distorted. The madreporite is widely separated from oculars II and III, against which the two columns of interambulacrum 2 abut as usual; genital 5 is similarly separated from oculars V and I, the periproct reaches the interambulacral areas at several points. Pages 52, 63.

Strongylocentrotus dröbachiensis (O. F. Müller).

Fig. 6. York Harbor, Maine. Diam. 42 mm. R. T. J. Coll., 781. × 3.8. Partially tetramerous specimen. Ambulacrum IV fails to reach the apical disc, so that interambulacra 3 and 4 are in contact dorsally; there are five oculars and genitals, ocular III and genital 5 are split by median sutures (p. 170); extra genital pores occur, two of which are in interambulacrum 3. Page 44.

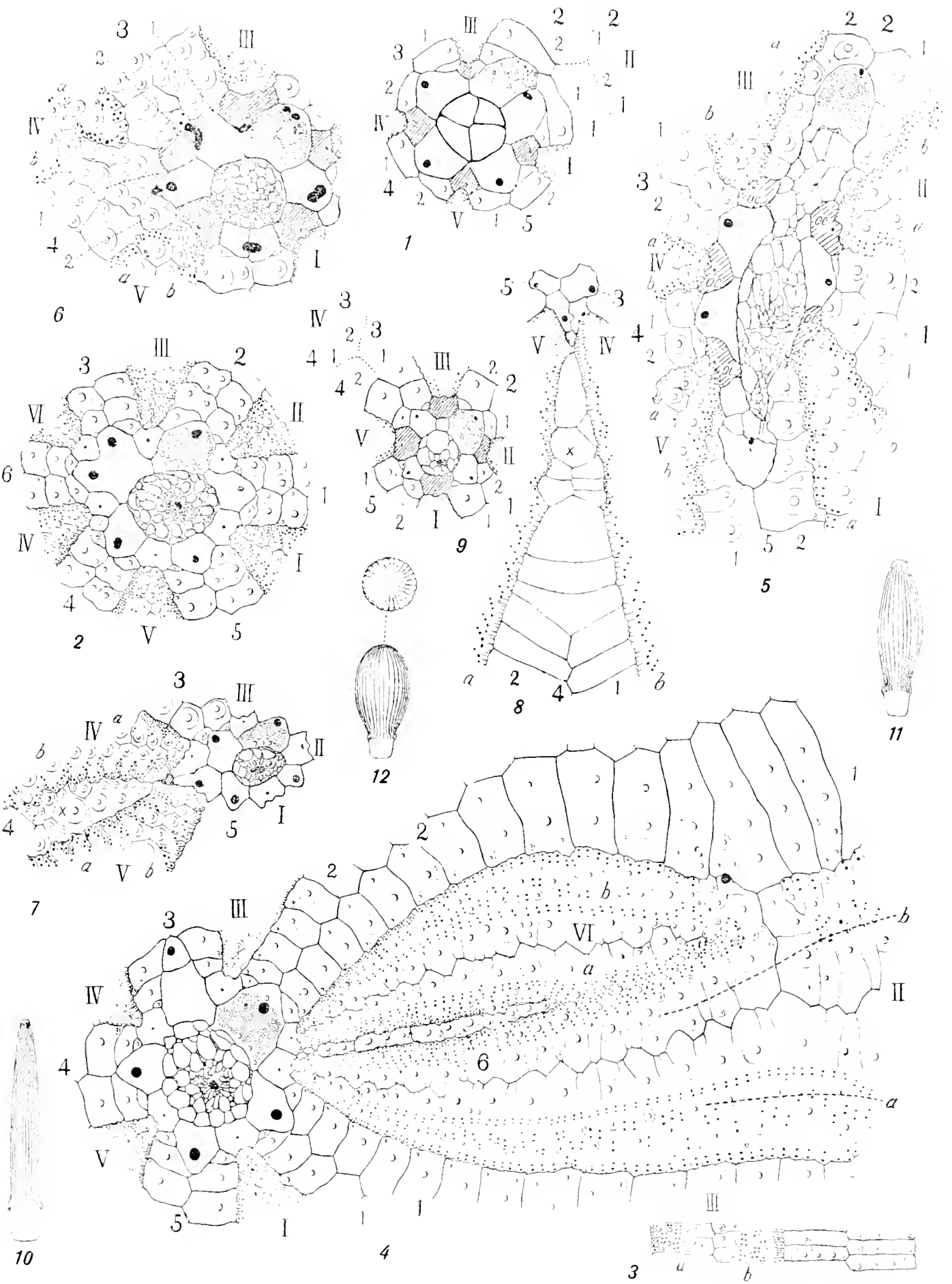
Fig. 7. Massachusetts Bay. Diam. 37 mm. R. T. J. Coll., 780. × 2.8. Partially tetramerous in that genital 4 is wanting, oculars IV, V are in contact, interambulacrum 4 dorsally has in part a single column of plates, as in Arbacia Plate 4, fig. 11. Page 45.

Fig. 8. The same specimen seen from within. × 2.8. To show the partially single column of interambulacral plates in area 4. Page 45.

Fig. 9. Sullivan, Maine. Diam. 14 mm. R. T. J. Coll., 664. × 5. Completely tetramerous specimen; there are four teeth, eight primordial ambulacral plates, four ambulacral and interambulacral areas, four oculars and genitals. The absent parts are ocular and ambulacrum IV, the right half of interambulacrum 3, and the left half of interambulacrum 4. From this structural deficiency the right half of interambulacrum 4, which is related to ocular V, and the left half of interambulacrum 3, which is related to ocular III, come together and are in contact throughout their length. (Compare Plate 6, fig. 1, and Plate 7, fig. 2; text-fig. 218, p. 191.) Page 38.

Figs. 10–12. Locality (?) Peabody Museum, Salem. × 5.6.

Fig. 10. A normal spine to compare with Figs. 11, 12 which are abnormally inflated and rounded. A unique variant in the species and family. Page 78.



HENRY BLAKE DEL. HELIOT. PE. CO. BOSTON.

PLATE 7.

Arbacia punctulata (Lamarck).

Fig. 1. Woods Hole, Massachusetts. Diam. 11 mm. R. T. J. Coll., 785. × 3.8. A partially tetramerous specimen; there are four ambulacra, but all other parts are in fives. Ambulacrum IV is wanting, so that interambulacra 3 and 4 are in contact throughout; extra interambulacral plates are developed as space fillers in this area. Page 41.

Toxopneustes variegatus (Lamarck).

Fig. 2. Tampa Bay, Florida. Measures 67 mm. through the axis II, 4. R. T. J. Coll., 749. × 1.9. Partially tetramerous; five ambulacra and interambulacra ventrally, dorsally above the ambitus there are four ambulacra, interambulacra and oculars, but five genitals. Ocular II lies just below the ambitus and to it extend ambulacrum II, the right half of interambulacrum 1, and the left half of interambulacrum 2. Above this zone the left half of interambulacrum 1 and the right half of interambulacrum 2 are in contact to the apical disc, where they abut against oculars I and II as usual (Compare p. 35; Plate 6, figs. 1, 9; text-fig. 218, p. 191.) Page 42.

Strongylocentrotus dröbachiensis (O. F. Müller).

Fig. 3. York Harbor, Maine. Diam. 37 mm. R. T. J. Coll., 662. × 5. Almost completely tetramerous, with four teeth, eight primordial ambulacral plates, four ambulacra, and interambulacra, four oculars, but five genitals. Genital 1 is a depauperate imperforate plate lying between ocular I and genital 2. The absent parts are ocular and ambulacrum II, the right half of interambulacrum 1 and the left half of interambulacrum 2. Oculars I, V are insert as usual An extra pore occurs in genital 4. (Compare Plate 6, figs. 1, 9.) Page 40

Fig. 4. York Harbor, Maine. Diam. 17 mm. R. T. J. Coll., 786. × 3.7. Partially tetramerous; ventrally there are five teeth, ambulacra and interambulacra, dorsally only four ambulacra, but the interambulacra and other parts are in fives. Ocular II is imperforate, ambulacrum II exists for only a short distance ventrally, above which interambulacra 1 and 2 are in contact, and some extra interambulacral plates are developed as space fillers. An accessory plate (split off?) lies between oculars 1, II and genitals 1, 5. Page 43.

Fig. 5. York Harbor, Maine. Diam. 51 mm. R. T. J. Coll., 784. × 2.8. Partially tetramerous; ventrally there are five teeth, in the corona five ambulacra, but only four interambulacra, also four oculars and genitals. Ocular II may be considered double as it has two pores related apparently to ambulacra I and II. There is no trace of interambulacrum 1; ambulacra I and II are in contact throughout their extent. Page 41.

Fig. 6. Frenchman's Bay, Maine. Diam. 36 mm. R. T. J. Coll., 783. × 3 Genital 3 is split by one horizontal suture, and genital 2 is split into three plates. (Compare Echinothuriidae.) Page 168.

Fig. 7. Dumpling Islands, North Haven, Maine. Diam. 14 mm. R. T. J. Coll., 848. Completely hexamerous specimen, the apical disc. × 7.7. Six ambulacra, interambulacra, oculars and genitals, but genitals 3 and 6 are fused. The added parts lie between oculars III and IV. (Compare Plate 6, fig. 2; Plate 8, fig. 3.) Page 47.

Fig. 8. Same specimen, peristome. × 4. There are six teeth, twelve primordial ambulacral plates and actinal cuts, six ambulacra and interambulacra Page 47.

Echinarachnius parma (Lamarck).

Fig. 9. Chelsea Beach, Massachusetts. Diam. 60 mm. Boston Soc. Nat. Hist Coll., 348. × 1.4. Partially hexamerous; there are five ambulacra and interambulacra ventrally, six ambulacra and interambulacra dorsally; the added areas lie between interambulacrum 1 and ambulacrum II. In the basicoronal row the five primordial interambulacral plates and the ten primordial ambulacral plates are in place as usual. Of the latter, the *Ia*, *IIa*, *IIIb*, *IVa*, *Vb* are larger as usual by Lovén's law. Same specimen as photograph, Plate 8, fig. 4. Page 49.

HENRY BLAKE DEL. HELIOTYPE CO. BOSTON.

PLATE 8.

Bothriocidaris pahleni Schmidt. Page 242.

Fig. 1. Diluvial-Geschichte, Ordovician, Rostov, Russia. Height 16.2 mm., diam. 16 mm., from a plaster cast, Mus. Comp. Zool. Coll 3,082 (from R. T. J. Coll.). Original at Rostov. × 2. Two columns of high hexagonal plates in each ambulacral area and one column of plates in each interambulacral area, the latter darkened for contrast. (Compare drawing of another specimen, Plate I, fig. 3.)

Arbacia punctulata (Lamarck). Page 39.

Fig. 2. Woods Hole, Massachusetts. Almost completely tetramerous, but there are five genital plates. The wanting parts are a tooth and ocular II, with its associated parts, which are ambulacrum II, the left half of interambulacrum 2, and the right half of interambulacrum 1. Same specimen as Plate 6, fig. 1.

Strongylocentrotus dröbachiensis (O. F. Müller). Page 47.

Fig. 3. Dumpling Islands, North Haven, Maine. R. T. J. Coll., 838. Natural size. Completely hexamerous; structure exactly as in Plate 7, fig. 7. This specimen is oriented and the additional area calculated from the oculars I, V insert, the position of the madreporite and the fused genitals.

Echinarachnius parma (Lamarck). Page 49.

Fig. 4. Partially hexamerous. Natural size. Pentamerous ventrally, but a sixth ambulacrum and interambulacrum are added dorsally. Same specimen as Plate 7, fig. 9.

Archaeocidaris wortheni Hall. Page 259.

Fig. 5. St. Louis Group, Lower Carboniferous, St. Louis, Missouri, Amer. Mus. Nat. Hist. $\frac{7}{1}\frac{747}{}$, cotype. Natural size. Ventral view, showing narrow ambulacral areas and four columns of plates in each interambulacrum. The basal terrace is clear on interambulacral plates. The peristome and lantern are in part preserved orally. This is one of the two most nearly complete specimens known in the genus. Drawings, Plate 9, figs. 6–8.

Fig. 6. Same specimen. Dorsal view. Primary spines and lantern in place.

Archaeocidaris legrandensis Miller and Gurley. Page 260.

Fig. 7. Keokuk Group, Lower Carboniferous, Boonville, Missouri. Univ. of Chicago Coll., 8,855. × 1.5. There are four columns of plates in each interambulacrum. Drawing, Plate 9, fig. 12.

Fig. 8. Same locality. Museum and Cat. no. as fig. 7. × 1.5. With primary and secondary spines in place. Drawing, Plate 9, fig. 13. These two specimens are the cotypes of *Eocidaris blairi* Miller, here considered a synonym.

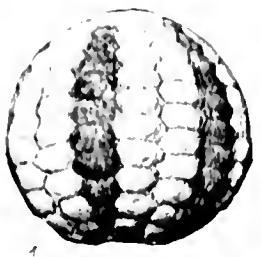
Archaeocidaris newberryi Hambach. Page 269.

Fig. 9. St. Louis Group, Lower Carboniferous, St. Louis, Missouri. F. Springer Coll. 8,119 (from G. Hambach Coll.), holotype. Natural size. Drawing, Plate 13, figs. 15a, 15b.

Archaeocidaris triserialis (M'Coy). Page 275.

Fig. 10. Arenaceous Limestone, Lower Carboniferous, Killycloghy, Lisbellow, County Tyrone, Ireland. Griffith Coll., Science and Arts Museum Coll., Dublin, holotype. Natural size. The specimen consists of spines only.

Figs. 1, 2, 4–9 photographed by F. A. Saunderson; fig. 3 photographed by H. W. Tupper; fig. 10 photographed in Dublin by A. C. Bridle.



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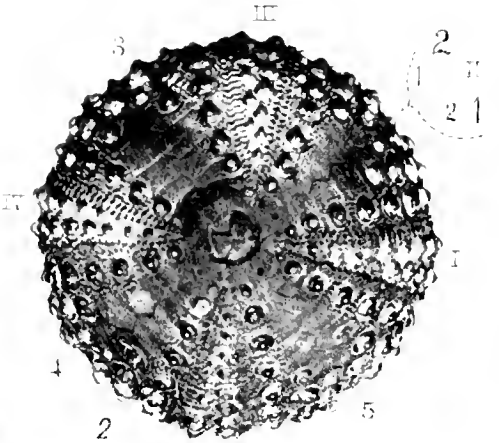
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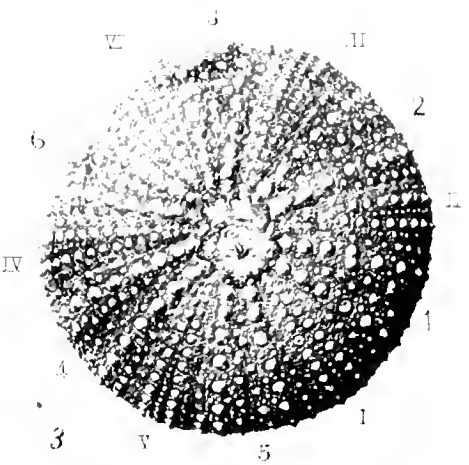
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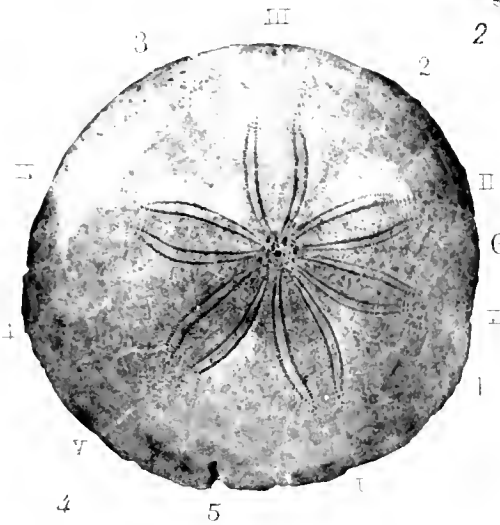
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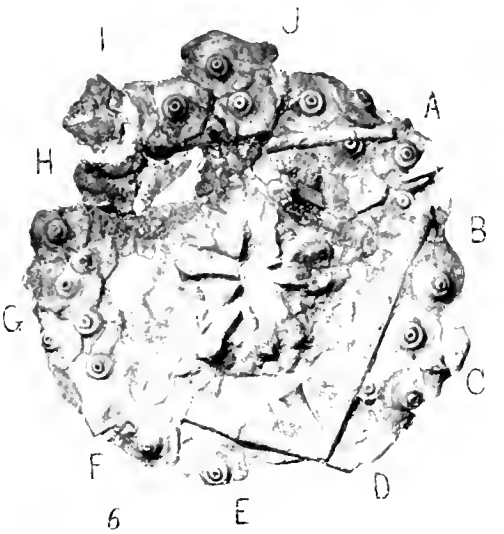
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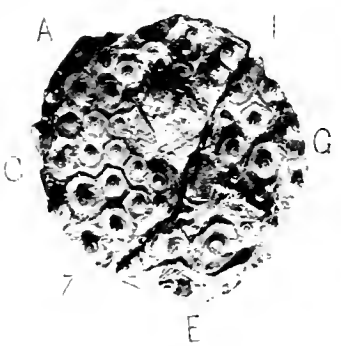
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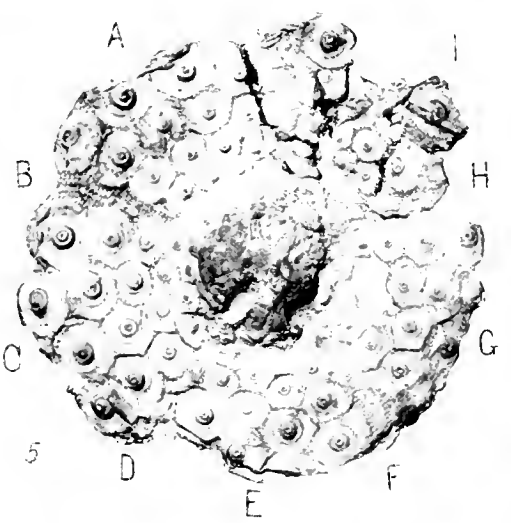
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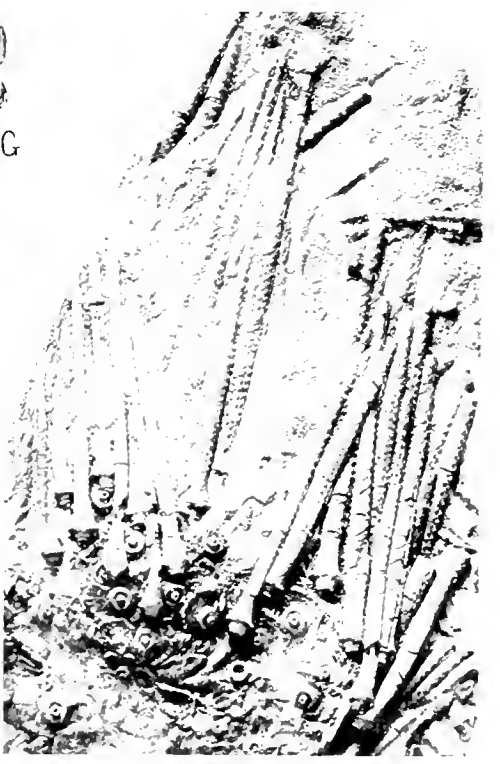

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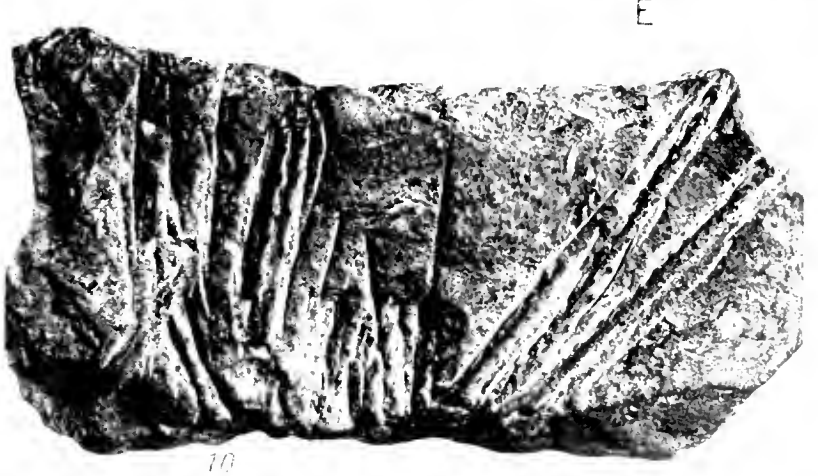

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PLATE 9.

Miocidaris keyserlingi (Geinitz). Page 245.

Fig. 1. Lower Zechstein, Permian, Corbusen, Germany (after Geinitz, 1848, Plate 7, fig. 2). Cotype. Natural size, and enlarged. Spine swollen, finely muricate.

Fig. 2. Zechstein, Permian, Corbusen, Ronneburg, Germany. Dresden Museum, cotype. × 7.5. Two columns of pentagonal plates in an interambulacrum. Redrawn from my sketch of the specimen in the Dresden Museum.

Fig. 3. Permian, Humbleton Hill, England. Enlarged, after King, 1850, Plate 6, fig. 22, where in the description of the plate this figure, with the two following, are called *Palaechinus verneuilianus* King, and in the text they are called *Archaeocidaris verneuiliana* King. Cotype of that species (here considered a synonym).

Fig. 4. Permian, Tunstall Hill, England. Spine. × 2.8. After King, 1850, Plate 6, fig. 24. Cotype of *Archaeocidaris verneuiliana* King, here considered a synonym.

Fig. 5. Probably referable to this species, Permian, Humbleton Hill, England. Enlarged. After King, 1850, Plate 6, fig. 24. Cotype of *Archaeocidaris verneuiliana* King, here considered a synonym.

Archaeocidaris wortheni Hall. Page 259.

Fig. 6. Same specimen as photographs, Plate 8, figs. 5, 6. Cotype. × 1.8. Two columns of plates, all similar, in each ambulacral area and four columns of plates in each interambulacral area from the basicoronal row up. In the basicoronal row of the interambulacral areas the plates are nearly or quite whole plates, alternating with half-plates, due to ventral resorption. In areas A and C in this row, the plates of columns 1 and 4 are large and the plates of columns 3 and 2 small. On the contrary, in areas E and G in this row, the plates of columns 1 and 3 are small and the plates of columns 4 and 2 are large. (Compare fig. 8.) Ventrally pyramids are in place, and ambulacral with interradial non-ambulacral peristomal plates are on the peristome. (Compare text-fig. 26, p. 70.)

Fig. 7. The same, restored to show a complete peristome and basicoronal row of the corona. × 1.8. (Compare text-figs. 47, p. 80; 239 *bis*, p. 264.)

Fig. 8. The same restored, showing the ventral border of the corona as in fig. 7, and the plates which have been removed by resorption restored theoretically. In interambulacral areas A and C, column 4 originates to the right of the center, and in interambulacral areas E, G, and I, column 4 originates to the left of the center, thus producing the system of alternation of large and small plates seen in the basicoronal row of the several areas. (A similar occurrence of the initial plate of column 4 being on the left of the center, or on the right of the center is seen in *Melonechinus multiporus*, text-fig. 245, p. 382.)

Figs. 9–11. St. Louis Group, Lower Carboniferous, St. Louis, Missouri. Amer. Mus. Nat. Hist. $\frac{7.1.4.7}{1}$, cotypes, being part of the same lot as fig. 6.

Fig. 9. Plates showing scrobicular ring, basal terrace, primary and secondary spines. × 1.9.

Fig. 10. Pyramid with epiphyses, brace and tooth, the last restored dorsally as indicated by dotted lines. × 3.6.

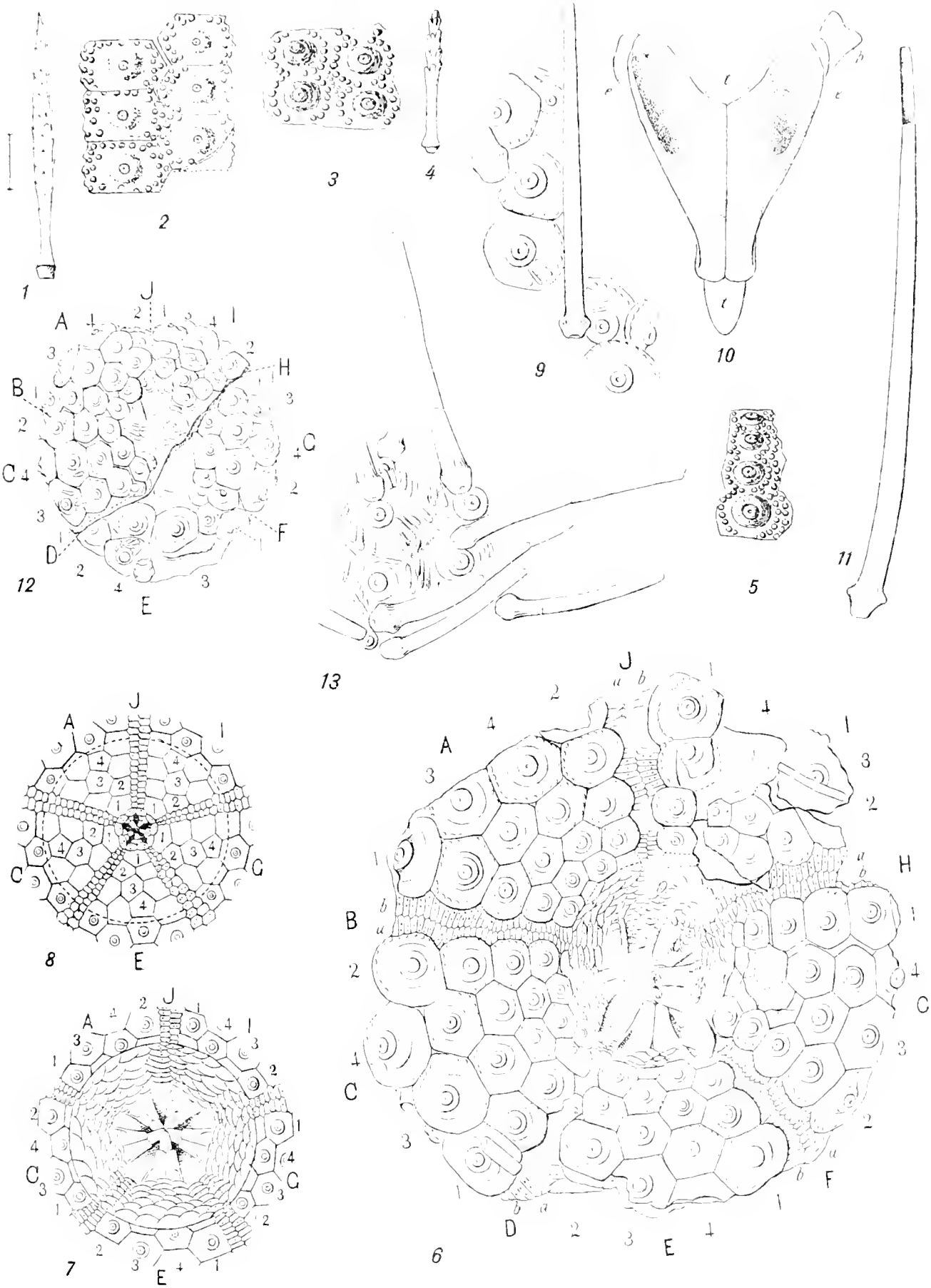
Fig. 11. Nearly entire primary spine, which is slender, smooth, terete, somewhat arcuate. × 1.9.

Archaeocidaris legrandensis Miller and Gurley. Page 260.

Fig. 12. Same specimen as photograph, Plate 8, fig. 7. × 1.8. Four columns of plates in each interambulacral area. The plates have a basal terrace well defined (see description of fig. 13).

Fig. 13. Same specimen as photograph, Plate 8, fig. 8. ×, 3.7. Part of the test with smooth, terete primary spines and small secondary spines in place. (These two specimens, figs. 12 and 13, are the cotypes of *Eocidaris blairi* Miller, here considered a synonym.)

Figs. 1–5 drawn by W. M. Barrows; figs. 6–13 by J. Henry Blake.



HENRY BLAKE, & M. BARBOAS DEL

JACKSON & BUTLER

PLATE 10.

Archaeocidaris longispina Newberry. Page 261

Fig. 1. Carboniferous (Coal Measures), North Arizona. Columbia Univ. Coll. 6,419 G, holotype. Natural size. Spines smooth, straight, inflated.

Archaeocidaris glabrispina (Phillips). Page 261.

Fig. 2. Lower Carboniferous, Hook Head, Ireland. Sedgwick Museum, Cambridge, England. a, spine × 1.9; b, base of spine more enlarged. The spine is smooth, straight, inflated.

Archaeocidaris legrandensis Miller and Gurley. Page 260.

Fig. 3. Kinderhook Group, Lower Carboniferous. Le Grand, Iowa. Univ. of Chicago Mus. Coll., 12,344 × 3.7. Four columns of plates in an interambulacral area, scrobicular ring well developed.

Fig. 4. Same horizon and locality. Univ. of Chicago Coll., 6,198, holotype. × 1.8. Interambulacral plates with smooth primary spines in place.

Archaeocidaris nerei (Münster). Page 262.

Fig. 5. Lower Carboniferous, cotypes, enlarged. × about 2. (After Münster, 1839, Plate 3, figs. 6a–6d.) a, an adradial interambulacral plate; b, spine; c, possibly a brace of the lantern; d, a left half-pyramid.

Figs. 6, 7. After Muller, 1857, Plate 3, figs. 12, a, b. × 2.7.

Fig. 6. Pyramid, face view, moderately deep foramen magnum (p. 363).

Fig. 7. Pyramid in side view with ridges for the attachment of interpyramidal muscles.

Archaeocidaris glabrispina (Phillips). Page 261.

Fig. 8. Lower Carboniferous, Limestone, Ireland (after Baily, 1877, p. 18, figs. a–e). Cotypes of *Archaeocidaris stellifera* Baily, here considered a synonym. Details of plate ornamentation in figs. a–c are very doubtful; d, spine, smooth, swollen; e, base of same enlarged

Fig. 9. Lower Carboniferous, Miatschkowa, near Moscow, Russia (after Trautschold, 1879, Plate 2, fig. without a number). The holotype of *Archaeocidaris lacris* Trautschold, here considered a synonym. Spine smooth, inflated.

Archaeocidaris rossica (Buch). Page 263.

Fig. 10. Lower Carboniferous, Miatschkowa, Province of Moscow, Russia. Palaeontological Museum, Munich. × 1.8. Same specimen as Plate 11, figs. 1, 2, spread out on the Lovén method. Ambulacra conform to the outline of the interambulacra, four columns of plates in each interambulacrum. Interambulacral plates are high hexagonal, elongating dorsally. Basal terrace developed, but wanting in the younger plates dorsally; primary tubercles imperforate in younger plates dorsally, and in the youngest plates there is no tubercle developed. In areas A, G, and I, the plates of the basicoronal row from left to right (of the area) are in the sequence of a large plate, small plate; large plate, small plate. Therefore column 4 lies to the right of the center. In areas C and E, on the contrary, the sequence from left to right is a small plate, then a large one; another small plate and a large one. In this arrangement column 4 lies to the left of the center. This relation of the sequence of large and small plates in the basicoronal row, and its relation to the position of column 4 will be understood by the schematic figure Plate 9, fig. 8, where the plates removed by resorption are restored in accordance with the rules observed in other Palaeozoic Echini. Strongly imbricating scale-like ambulacral and non-ambulacral plates occur on the peristome. (See text-fig. 239 *bis*, p. 264.)

Archaeocidaris sixi Barrois. Page 117.

Fig. 11. Carboniferous, Assize de Leña, Ontoria, Selarga, Spain. Cotypes (after Barrois, 1882, Plate 16, figs. 5a–5c). a, b, interambulacral plate in face and side views. × 0.9. c, spine, flattened, vertically striate, the form of the cross section is shown above. × 2.8. On account of the small size and flattening, this is apparently a secondary not a primary spine.

Archaeocidaris pizzulana Gortani. Page 273

Fig. 12. Carboniferous, Forca Pizzul, Carnic Alps, Italy, cotypes (after Gortani, 1905, Plate 15, figs. 29, 30, 31, 33). a, b, interambulacral plates; c, primary spine with thorn-like spinules set opposite one another. × 0.9. d, base of spine showing annulus.

Figs. 5 and 9 drawn by W. M. Barrows; all others by J. Henry Blake

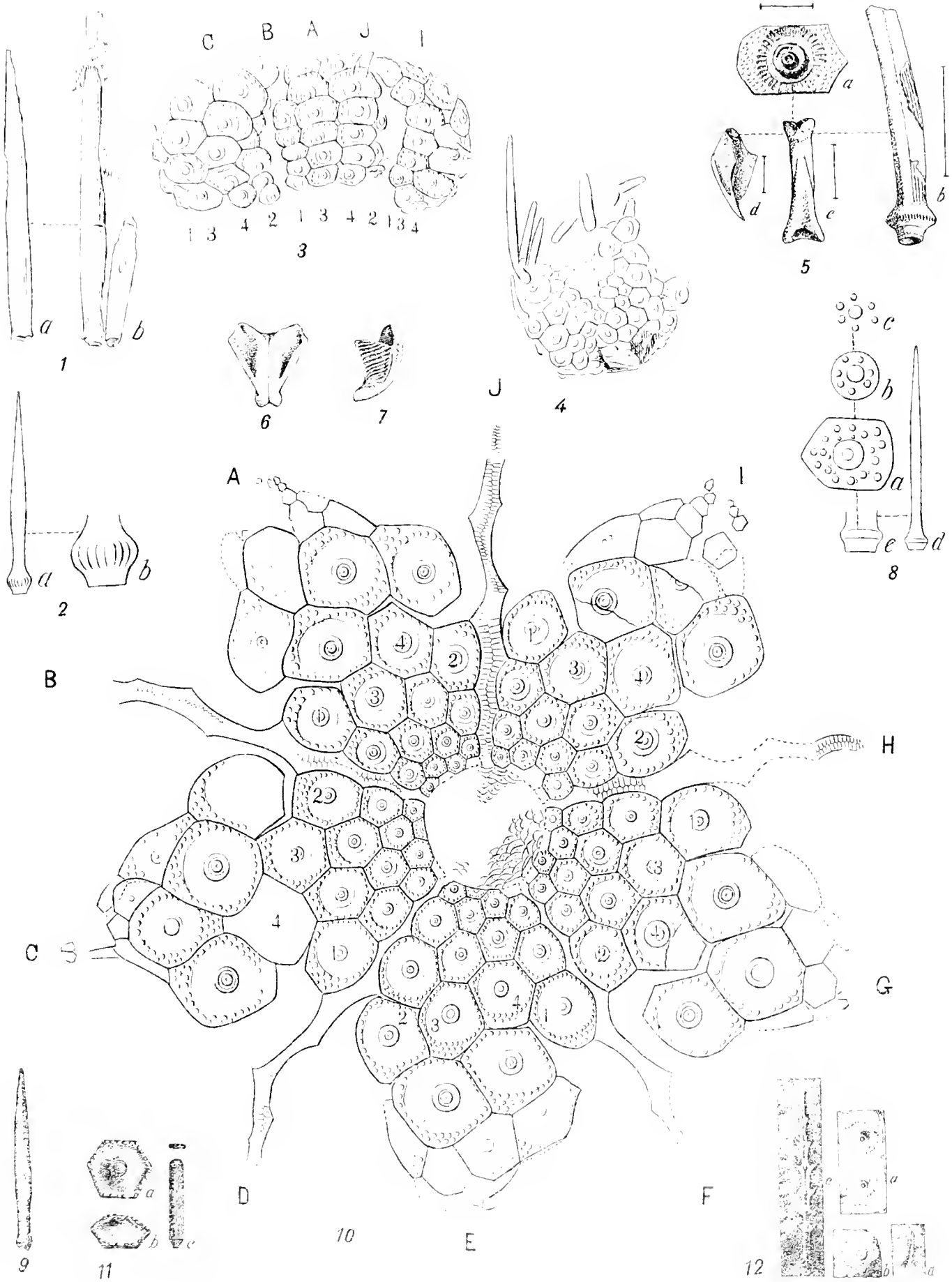

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PLATE 11

Archaeocidaris rossica (Buch) Page 263.

Figs. 1–5. Lower Carboniferous, Miatschkowa, Province of Moscow, Russia.

Fig. 1. Ventral view of a nearly perfect specimen. Diameter through A, F 46 mm. Palaeontological Museum, Munich. × 2. Ambulacra are best preserved in areas H and J; four columns of plates in each interambulacral area. Interambulacral plates are higher than wide, increasing in height to the ambitus. Basal terrace moderately strong, with large scrobicular area (seen better in fig. 4); the flange bearing secondary tubercles, is wider in the ventral and dorsal portion of each plate. On the peristome there are many small scale-like imbricating ambulacral and interradial non-ambulacral plates.

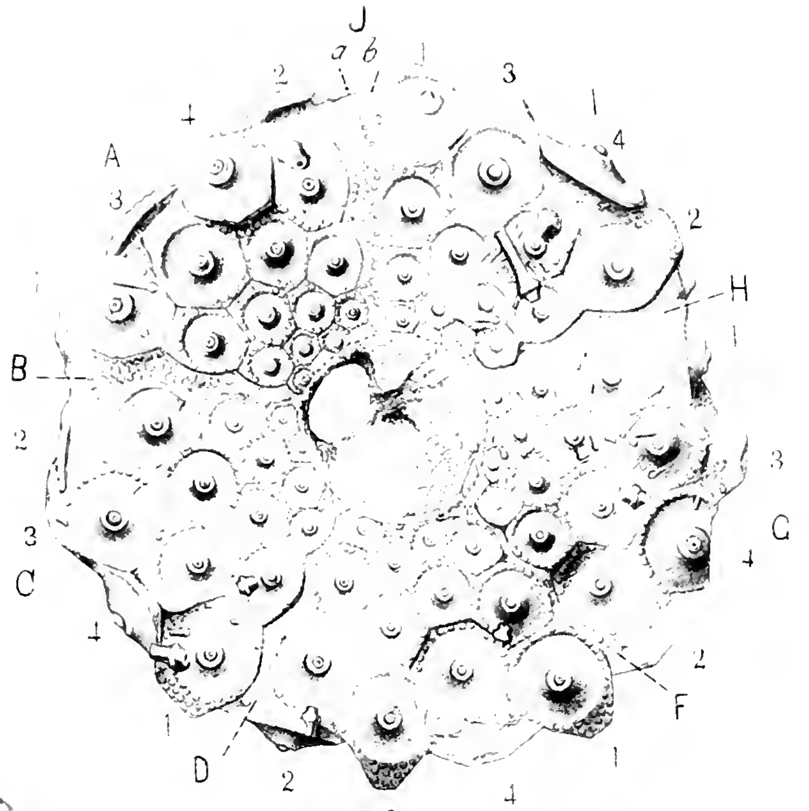
Fig. 2. Same specimen, dorsal view. × 2. Interambulacral plates are much higher than ventrally, the basal terrace is wanting dorsally, although the tubercles are well developed still further dorsally as seen in a plate in column 3 of area C, the young tubercle is imperforate, as in young tubercles of recent Cidaridae, Plate 3, figs. 1, 2. In the youngest interambulacral plates, seen best in area I, no tubercle is yet developed. Within the center are many small periproctal plates. This, which is shown spread out on the Lovén method in Plate 10, fig. 19, is the most complete specimen known in the genus.

Fig. 3. The same. × 8. Enlargement of periproctal plates; the two larger plates are possibly ocular and genital, from area D of fig. 2.

Fig. 4. Interambulacral plate showing perforate mamelon, sunken platform with its elevated ring-like parapet, the boss bounded by the basal terrace, and a rather wide scrobicule within the scrobicular circle. On the margin of the plate are secondary and miliary tubercles. Secondary spines are vertically finely striate and miliary spines are in place; these are the only miliary spines so far known in specimens of the genus. Mus. Comp. Zool. Coll., 3,088 (from R. T. J. Coll.). × 4.

Fig. 5. Base of primary spine, showing milled ring, fine vertical striation, and nodose spinules. Mus. Comp. Zool. Coll., 3,091 (from R. T. J. Coll.). × 4. (Compare Plate 12, figs. 13a–13k.)

Figs. 1–3 drawn by Anton Birkmaier; figs. 4, 5 drawn by J. Henry Blake.



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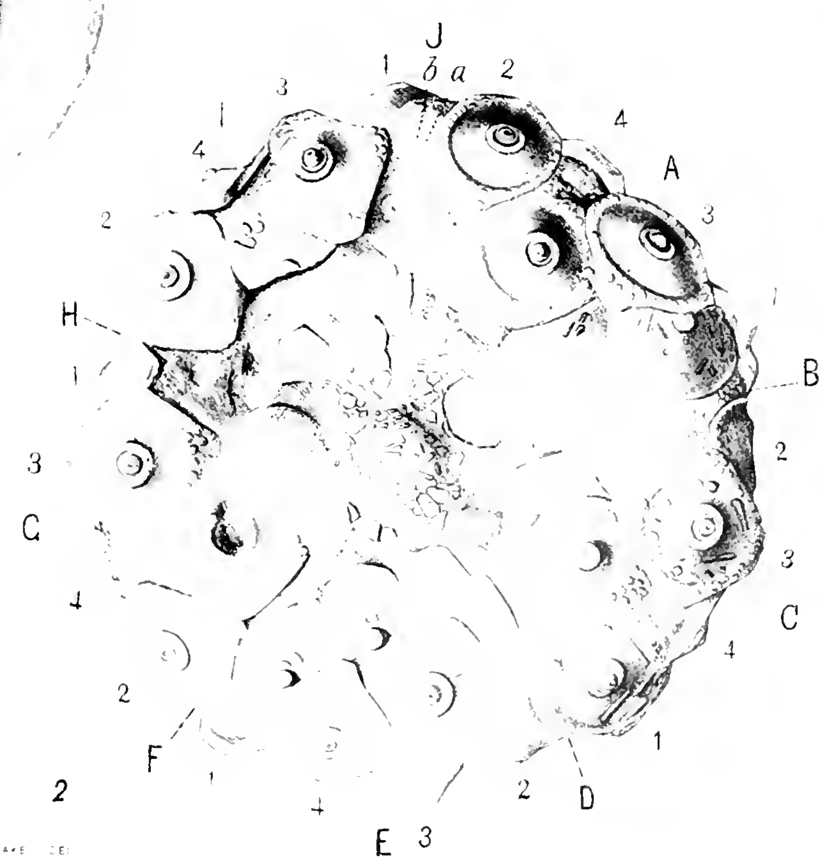

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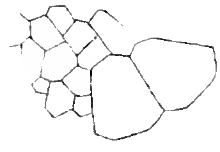

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B. MEISEL . HENRY BLAKE, DEL. HELIOTYPE CO. BOSTON

PLATE 12.

Archaeocidaris rossica (Buch). Page 263.

Figs. 1–13. Lower Carboniferous. Miatschkowa, Province of Moscow, Russia.

Fig. 1. Mus. Comp. Zoöl. Coll., 3,086 (from R. T. J. Coll.). × 4. Dorsal view of two half-pyramids with epiphyses, brace, and compass in place; this is the most nearly perfect specimen of a compass seen from the Palaeozoic (p. 182).

Fig. 2. The same restored.

Fig. 3. Mus. Comp. Zoöl. Coll., 3,084 (from R. T. J. Coll.). × 4. Face view of the upper part of two half-pyramids with epiphyses and a brace in place. The space between the half-pyramids, which is occupied by the interpyramidal muscle, is narrower than normal because the half-pyramids are somewhat out of place, compare fig. 5.

Figs. 4–6. A very fine lantern in the Palaeontological Museum, Munich.

Fig. 4. Pyramid face view. × 4. Braces and tooth in place, foramen magnum moderately deep.

Fig. 5. Ventral view. × 4. The pyramids curve laterally, giving spaces for long interpyramidal muscles, the lantern is strongly inclined, as is obvious from the amount of the pyramids seen from this view.

Fig. 6. The same specimen, dorsal view. × 4. Epiphyses, braces, and teeth in place, the foramina magna moderately deep. (Figs. 4–6, compare text-fig. 208, p. 184.)

Fig. 7. Mus. Comp. Zoöl. Coll., 3,085 (from R. T. J. Coll.). Upper part of two half-pyramids, in sidewise view. × 4. Epiphyses, brace, and tooth in place; *p. s.*, pyramidal suture.

Fig. 8. Mus. Comp. Zoöl. Coll., 3,086 (from R. T. J. Coll.). × 4. Pyramid, side view, showing ridges for the attachment of interpyramidal muscle, epiphysis with glenoid cavity, a displaced brace, and a tooth, the latter restored ventrally, as indicated by dotted lines.

Fig. 9. Mus. Comp. Zool. Coll., 3,087 (from R. T. J. Coll.). × 8. Ambulacral plates with an adjacent adradial plate. The ambulacral plates bevel strongly under the adradials as seen on the right. On the left the ambulacrum is pushed out of place under the adradial plate. Outline of ambulacrum undulate, conforming to the outline of the interambulacrum. (Compare Plate 10, fig. 10.)

Fig. 10. The same, ambulacral plate, in side view to show the adradial bevel. × 4.

Fig. 11. Mus. Comp. Zoöl. Coll., 3,084 (from R. T. J. Coll.). × 4. A plate not in place, perhaps a genital, seen from the interior.

Fig. 12. Mus. Comp. Zoöl. Coll., 3,087 (from R. T. J. Coll.). Natural size. Test, ventral view. The limit of the upper part of the figure is about on the line of the ambitus.

Fig. 13. Mus. Comp. Zoöl. Coll., 3,091. Natural size. Primary spines, showing their form and spinules. (Compare Plate 11, fig. 5.)

Figs. 1–3 and 7–11 drawn by J. Henry Blake; figs. 4–6 drawn by Anton Birkmaier; photographs by F. A. Saunderson.

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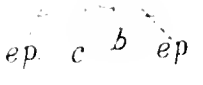

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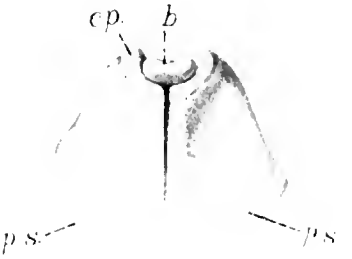

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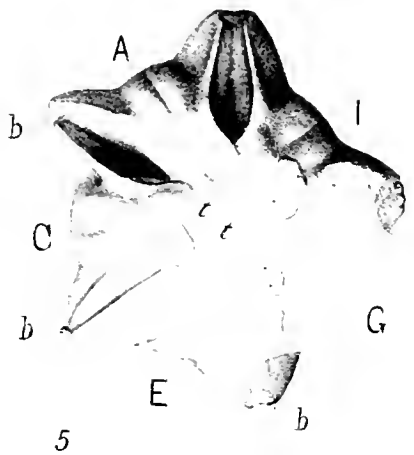

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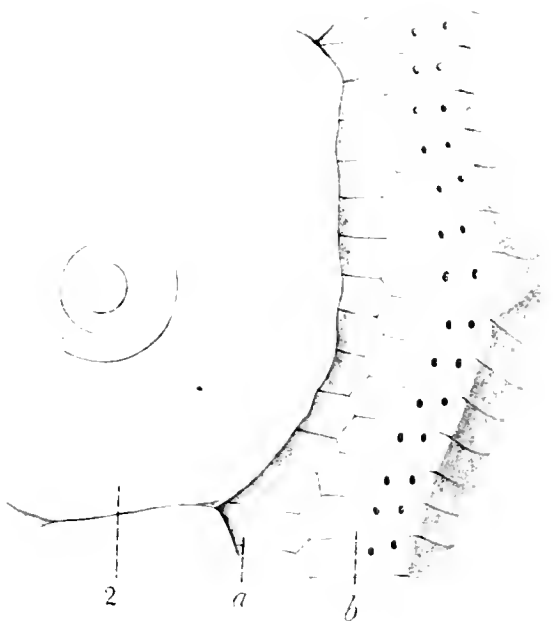

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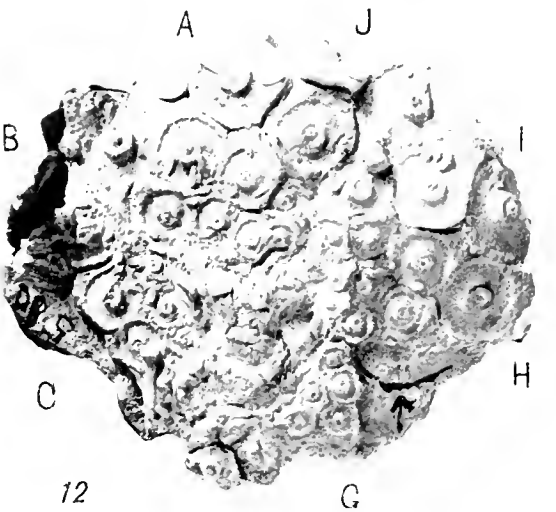

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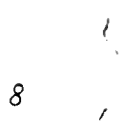
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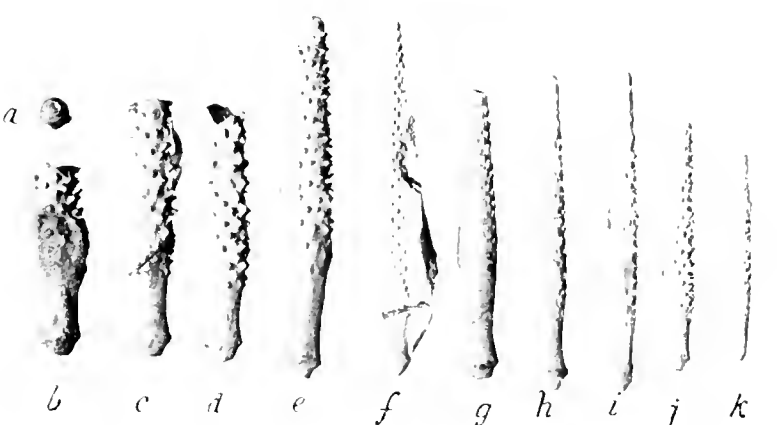

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PLATE 13.

Archaeocidaris agassizi Hall. Page 266.

Figs. 1–4. Burlington Limestone. Lower Carboniferous, Burlington, Iowa.

Fig. 1. After Hall, 1858, Plate 26, figs. 1b, 1c, 1d. Cotypes. a, plate enlarged, basal terrace clear; b, the same in profile; c, spine, which is elliptical in cross section. × 1.8.

Fig. 2. Univ. of Michigan Coll., 1,580. × 3.8. Pyramid with tooth in place, the pyramid dorsally and the tooth ventrally and dorsally are restored as indicated by dotted lines.

Fig. 3. F. Springer Coll., 8,100. × 1.8. Showing ambulacra, and four columns of interambulacral plates in area I; a few ambulacral plates are on the peristome.

Fig. 4. F. Springer Coll., 8,087. × 3.7. Ambulacral plates with lateral bevel, interambulacral plates, pyramid with epiphyses and brace. The perforated, elongate plates are unlike anything seen in other species; they may be genitals.

Archaeocidaris illinoisensis Worthen and Miller. Page 266.

Fig. 5. St. Louis Group, Lower Carboniferous, near Illinois Furnace, Hardin County, Illinois (after Worthen and Miller, 1883, Plate 31, fig. 1a, pars. fig. 1b). Cotypes. × 0.9. Spines swollen, with fine spinules.

Archaeocidaris coloradensis nom. nov. Page 267.

Fig. 6. Crinoidal Limestone, Upper Carboniferous, Northern Arizona. Columbia Univ. Coll., 6,900 G, cotype. × 0.9. Fragment from shaft of a primary spine, muricate.

Archaeocidaris keokuk Hall. Page 267.

Fig. 7. Keokuk Group, Lower Carboniferous, Warsaw, Illinois, (after Hall, 1858, Plate 26, figs. 2a, 2b) cotypes. a, plate enlarged, shows basal terrace; b, spine slightly enlarged, with numerous fine spinules.

Archaeocidaris gracilis Newberry. Page 267.

Fig. 8. Crinoidal Limestone, Upper Carboniferous, Cañon, Diamond River (Colorado ?). Columbia Univ. Coll., 603 and 604, holotype. × 0.9. Spine slender, bears fine spinules.

Archaeocidaris aculeata Shumard. Page 268

Fig. 9. Topeka Limestone, Carboniferous (Coal Measures), Topeka, Kansas. Indiana Univ. Geological Survey Coll. × 1.9. a, b, dissociated plates; c–f, spines with small irregularly placed spinules.

Archaeocidaris shumardana Hall. Page 268.

Fig. 10. Warsaw Limestone, Lower Carboniferous, Warsaw, Illinois (after Hall, 1858, Plate 26, figs. 3b–3d). Cotypes, a, plate enlarged; b, same in profile; c, spines with fine spinules. × 1.9.

Archaeocidaris edgarensis Worthen and Miller. Page 269.

Fig. 11. Upper Coal Measures, one mile east of Baldwinsville, Edgar County, Illinois (after Worthen and Miller, 1883, Plate 30, figs. 15a–15c). Cotypes. a, single plate; b, spine; c, base of spine, enlarged.

Fig. 12. Junietta Group, Carboniferous (Coal Measures), Manhattan, Kansas. J. W. Beede Coll. × 2.8. A right half-pyramid, face view, epiphysis wanting; *p. s.*, pyramidal suture.

Fig. 13. Same specimen, side view, with ridges for the attachment of interpyramidal muscle. × 2.8.

Fig. 14. Same specimen, inner view, showing pyramidal suture and dental slide. × 2.8.

Archaeocidaris newberryi Hambach. Page 269.

Fig. 15. Lower St. Louis Limestone, Lower Carboniferous, St. Louis, Missouri. F. Springer Coll., 8,119 (from G. Hambach Coll.), holotype. × 1.8. a, plates with primary and secondary spines in place; b, a nearly perfect primary spine, spinules directed distally, in series. Same specimen as photograph, Plate 8, fig. 9.

Archaeocidaris trudifer White. Page 269.

Fig. 16. Red Wall Limestone, Carboniferous (Coal Measures), Camp Apache, Navajo County, Arizona (after White, 1877, Plate 6, figs. 8a, 8b). U. S. Nat. Mus. Coll., 8,171, cotypes. × 0.9. a, hexagonal interambulacral plate; b, primary spine, restored proximally and distally as indicated; spinules directed distally, irregularly distributed.

Figs. 2–4, 8, 9, 12–15, drawn by J. Henry Blake; all others copied by W. M. Barrows.

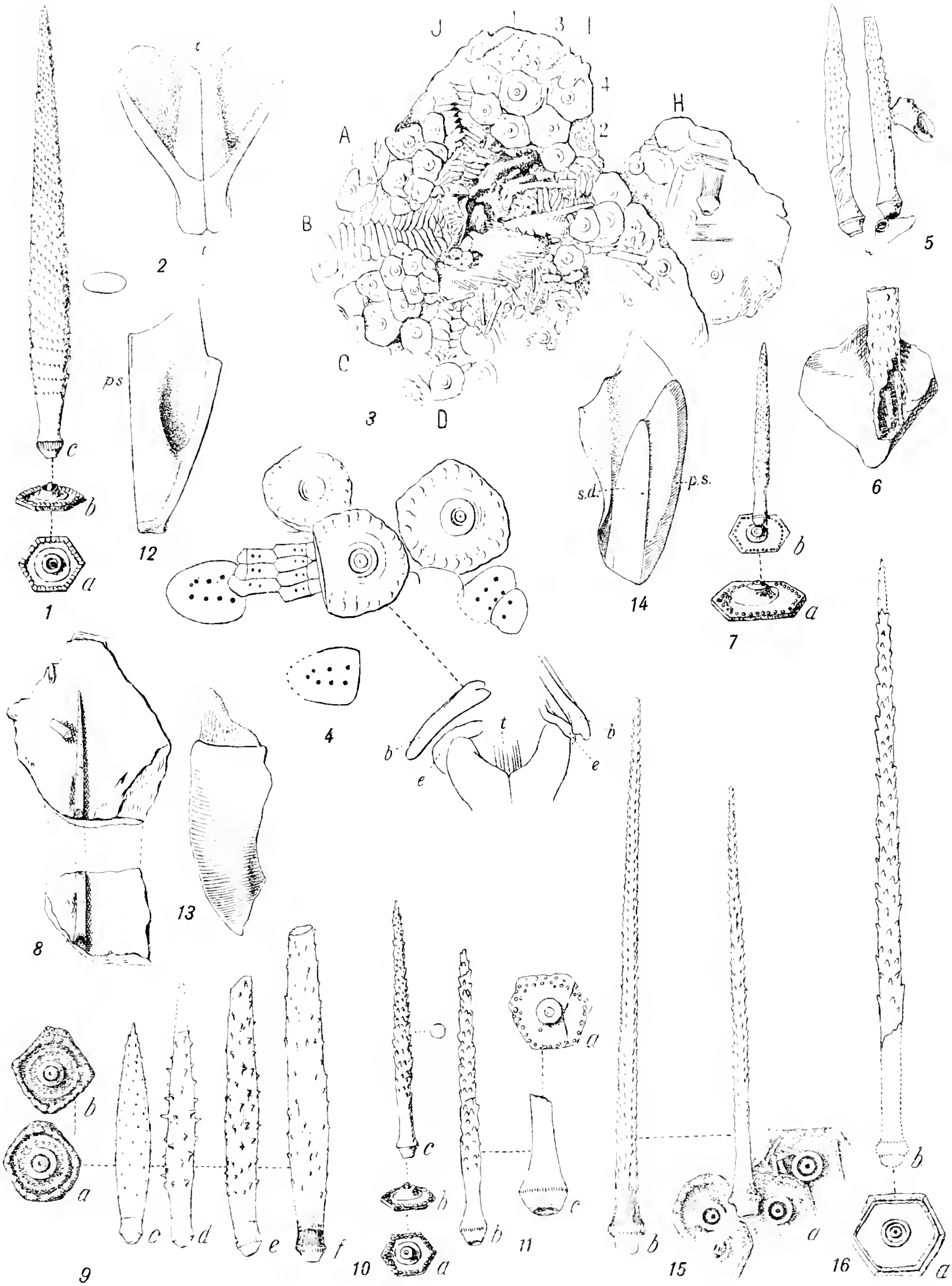


PLATE 14.

Archaeocidaris norwoodi Hall. Page 270.

Fig. 1. Kaskaskia Group, Lower Carboniferous, Chester, Illinois (after Hall, 1858, Plate 26, figs. 5b–5e), cotypes. a, adambulacral plate enlarged; b, the same in profile; c, spine nearly twice enlarged; d, base of same more enlarged; spinules small, or large, directed distally.

Archaeocidaris paradoxa (Eichwald). Page 270.

Fig. 2. Upper Carboniferous, Sterlitamak and Saranmsk, Ural (after Eichwald, 1860, Plate 32, fig. 25), cotype. × 0.9. Shaft of spine, spinules large, directed distally.

Archaeocidaris mucronata Meek and Worthen. Page 271.

Fig. 3. Chester Group, Lower Carboniferous, Liberty, Randolph County, Illinois (after Meek and Worthen, 1866, Plate 23, figs. 3a, 3c), holotype. × 0.9. a, hexagonal interambulacral plate from a median column; b, spine with large spinules directed distally.

Fig. 4. Upper Carboniferous, ten miles west of Ojo del Oso, near Fort Wingate, New Mexico (after White, 1877, Plate 6, fig. 7a, where it is referred to *A. ornatus* Newberry). U. S. Nat. Mus. Coll. 8,472. × 0.9. Distally and proximally restored as indicated by dotted lines.

Archaeocidaris dininnii White. Page 271.

Fig. 5. Upper Coal Measures, near Tecumseh, Nebraska (after White, 1880a, Plate 35, figs. 6a, 6b). U. S. Nat. Mus. Coll. 8,031, cotypes. × 0.9. a, b, primary spines, with spinules at right angle to the axis.

Archaeocidaris cratis White. Page 272.

Fig. 6. Upper Carboniferous, confluence of Grand and Green Rivers, Utah (after White, 1880a, Plate 33, fig. 2a, by error given as White, 1880, on my p. 272). U. S. Nat. Mus. Coll., 8,235, holotype. × 0.9. Spinules sparse, but large, directed distally.

Archaeocidaris acanthifera Trautschold. Page 272.

Fig. 7. Lower Carboniferous, Miatschkowa, near Moscow (after Trautschold, 1879, Plate 2, fig. 1a, the number is omitted on the Plate, but occurs in the description of the same, by error given as Plate 2, fig. 1 a on my p. 272). Holotype. Spinules irregularly distributed, long.

Fig. 8. Probably referable to this species. Carboniferous (Coal Measures), marine band, below the Gin-Mine coal, Nettlebank, North Staffordshire, England (after Hind, 1905, Plate 35, figs. 1, 1a, by error given as Plate 25 on my p. 272). Natural size. Spinules long.

Archaeocidaris biangulata Shumard and Swallow. Page 273.

Fig. 9. Hueco Formation, Carboniferous (Coal Measures), Diablo Mountains, Western Texas. U. S. Nat. Mus. Coll. × 2.8. a, adradial plate, basal terrace prominent; b, primary spine with serrate lateral flanges passing into spinules which distally are generally distributed; c, similar, but flange more pronounced; d, flange still wider.

Archaeocidaris ornata (Eichwald). Page 274.

Fig. 10. Lower Carboniferous, Miatschkowa, near Moscow (after Eichwald, 1860, Plate 32, fig. 24). Holotype. Spine densely covered with small spinules directed distally.

Archaeocidaris ourayensis Girty. Page 271.

Fig. 11. Hermosa Formation, Carboniferous (Coal Measures), Ouray, Colorado (after Girty, 1903, Plate 1, fig. 14). Holotype. U. S. Nat. Mus. Coll., 35,369. Somewhat enlarged. Spine densely covered with large spinules, directed distally.

Archaeocidaris triplex White. Page 274.

Fig. 12. Carboniferous (Coal Measures), near Taos, New Mexico (after White, 1881, Plate 1, figs. 3a–3c), cotypes. U. S. Nat. Mus. Coll. 9,449. × 0.9. a, small interambulacral plate, "probably this species"; b, spine triangular in section with spinules in three series directed distally. White says this figure is restored from fragments; c, section of spine.

PLATE 14 (*continued*).

Archaeocidaris megastyla Shumard and Swallow. Page 273.

Fig. 13. St. Louis Group, Lower Carboniferous, St. Louis, Missouri. U. S. Nat. Mus. Coll., 43,009. × 0.9. Interambulacral plates with primary and secondary spines in place, the primary having strong, thorn-like, widely spaced spinules.

Archaeocidaris triserialis (M'Coy). Page 275.

Fig. 14. Arenaceous Limestone, Lower Carboniferous, Killycloghy, Lisbellow, County Tyrone, Ireland (after M'Coy, 1844, Plate 26, fig. 1). Griffith Collection, Science and Arts Mus. Coll., Dublin. Holotype. × 0.9. Spines with three series of serrate spinules directed distally. Same specimen as photograph, Plate 8, fig. 10.

Archaeocidaris triserrata Meek. Page 275.

Fig. 15. Upper Carboniferous, near Omaha, Nebraska (after Meek, 1872, Plate 1, figs. 6a–6c). U. S. Nat. Mus. Coll. 6,599. Cotypes. a, base of spine, × about 4; b, c, spines with serrate spinules, enlarged a little less than × 2.

Archaeocidaris urii (Fleming). Page 276.

Fig. 16. Lower Carboniferous, Ireland (after Portlock, 1843, Plate 16, fig. 11, who figured it as *Cidaris vetusta*). Interambulacral plate. Natural size. (Probably the specimen in the Jermyn Street Museum, 7,768, see p. 278.)

Archaeocidaris wervekei Tornquist. Page 276.

Fig. 17. Lower Carboniferous, Hunsrücken, Germany (after Tornquist, 1897, Plate 22, figs. 2a, 2b, 3, 9, 10). Cotypes. a, hexagonal interambulacral plate, natural size; b, the same, enlarged, basal terrace pronounced; c, an adradial plate enlarged; d, a plate in profile; e, f, spine natural size, and detail enlarged with nodose spinules, arranged in vertical series.

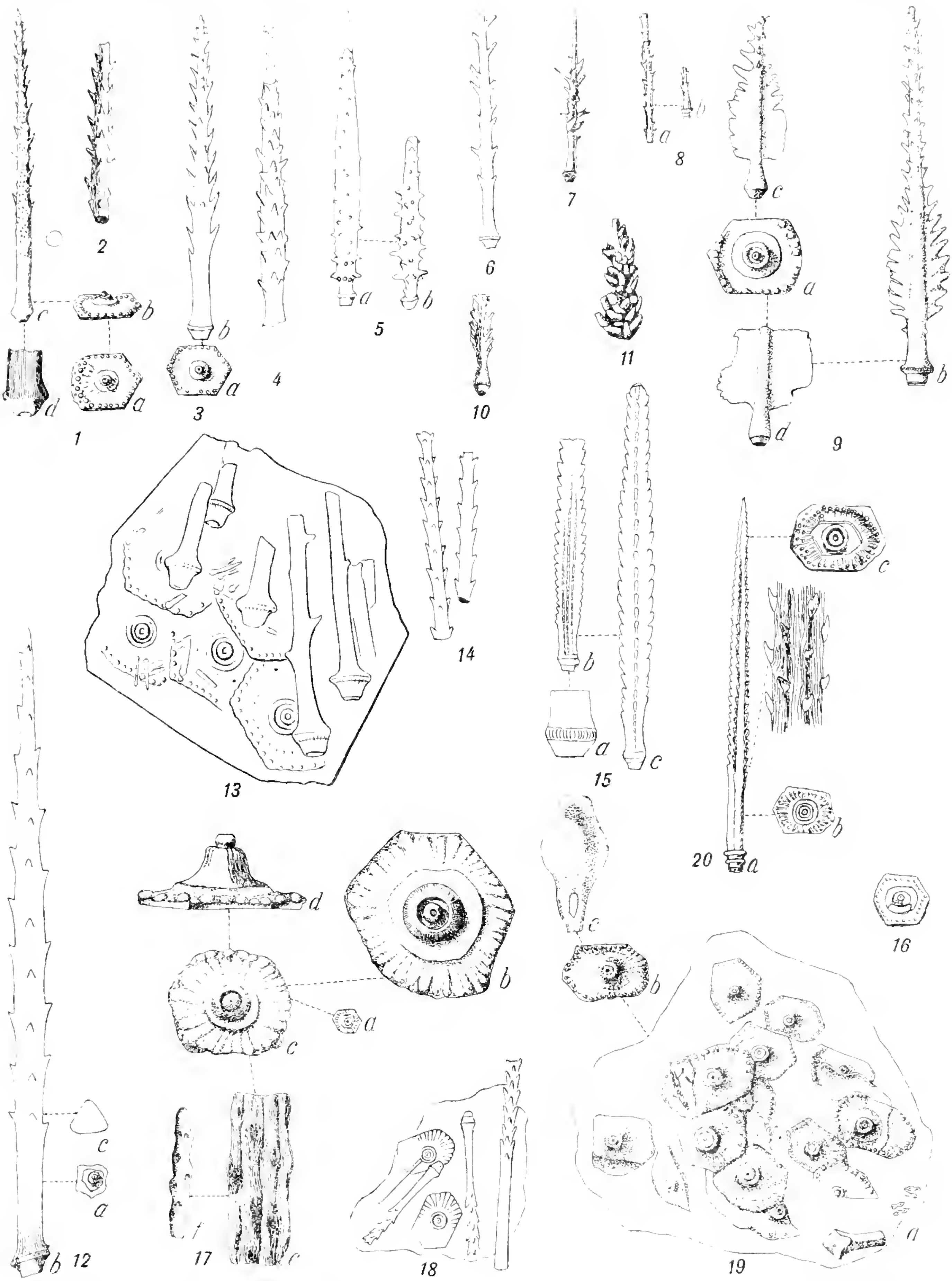
Archaeocidaris urii (Fleming). Page 276.

Fig. 18. Lower Carboniferous, Ireland (after M'Coy, 1844, Plate 27, fig. 1).

Fig. 19. Lower Carboniferous, Hayfod-y-Calch, Corwen, Wales; Sedgwick Museum, Cambridge (after Keeping, 1876, Plate 3, figs. 14, 15, 18). × 0.9. a, dissociated plates as they occur on the slab; b, an adradial plate, basal terrace clearly defined; c, a peculiar plate of unknown nature from fig. a, enlarged (p. 278).

Fig. 20. Lower Carboniferous, Benburb, County Tyrone, Ireland (for the locality of this specimen see discussion, p. 278) (after Portlock, 1843, Plate 16, figs. 10a–10d, where it is called *Cidaris benburbensis* Portlock, of which species it is the holotype). Museum of Practical Geology Coll., London, 7,659. a, spine, natural size and enlarged; b, c, plates, natural size.

Figs. 9 and 13 drawn by J. Henry Blake; all others copied by W. M. Barrows.



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JACKSON ON ECHINI.

PLATE 15.

Archaeocidaris urii (Fleming). Page 276.

Fig. 1. Lower Carboniferous, Knock Hill Quarry, Fife, Scotland. Museum of Practical Geology, London, 16,319. × 1.8. Showing coronal ambulacral plates and four columns in an interambulacrum, also some peristomal plates.

Fig. 2. Lower Carboniferous, Hunsrücken, Germany (after Tornquist, 1897, Plate 23, fig. 4). a, b, c, spine. × 0.9 and enlarged. Spinules pronounced, in series, directed distally.

Fig. 3. Culm, Lower Carboniferous, Königsberg, Germany (after Parkinson, 1903, Plate 15, fig. 13). The holotype of *Archaeocidaris regiomontana* Parkinson, here considered a synonym. A single interambulacral plate.

Archaeocidaris halliana (Geinitz). Page 279.

Fig. 4. Upper Carboniferous, Nebraska City, Nebraska (after Geinitz, 1866, Plate 5, figs. 1a, 1b, 2a, 2b). Cotypes. a, interambulacral plate, natural size and enlarged; b, spine enlarged × about 6. c, same much enlarged, with minute spinules in numerous vertical series.

Archaeocidaris muensteriana (Koninck). Page 280.

Fig. 5. Lower Carboniferous, Visé, Belgium (after Koninck, 1842–'44, Plate E, figs. 2a–2d). Cotypes. a, plate, × 0.9, and enlarged; b, spine, × 0.9; c, base of same enlarged, with minute spinules in numerous vertical series.

Archaeocidaris forbesiana (Koninck). Page 280.

Fig. 6. Productus Limestone, Salt Range, Permian, near Katta, Golawali, and Bazarwan, India (after Waagen, 1879–'87, Plate 95, figs. 5a, 7a, 13b, 14, 15). Natural size. a, b, imperfect interambulacral plates, c, base of spine; d, e, spines (cotypes), which are inflated with minute spinules in vertical series.

Archaeocidaris spinoclavata Worthen and Miller. Page 281.

Figs. 7a–7e. Middle and Lower Coal Measures, St. Clair and Marshall Counties, Illinois (after Worthen and Miller, 1883, Plate 30, figs. 14a, 14b, 14e). Cotypes. Plates hexagonal; spine distally enlarged, densely spinulose.

Figs. 7f–7h. After Meek and Worthen, 1873, Plate 24, figs. 13a, 13d, 13e, who figured them as Archaeocidaris (?) sp. Spines inflated, densely spinulose.

Archaeocidaris clavata (Eichwald). Page 282.

Fig. 8. Carboniferous, Yegorjefsk, Province of Kalonga, Russia (after Eichwald, 1860, Plate 33, fig. 16. By error given as Plate 23 on my p. 282. Holotype. Spine, inflated.

Archaeocidaris selwyni R. Etheridge, Jr. Page 447.

Fig. 9. Nowra Grit, Permo-Carboniferous, Nowra, Shoalhaven River, County St. Vincent, New South Wales (after R. Etheridge, Jr., 1892a, Plate 15, fig. 3) from casts of part of the plates of the holotype. × 0.9.

Fig. 10. Upper Marine Series, Permo-Carboniferous, Dagworth, about five miles south of West Maitland, County Northumberland, New South Wales (after R. Etheridge, Jr., 1892a, Plate 22, fig. 1 in part). Etheridge considered this distinct from *A. selwyni*. Natural size. Four columns of plates in an interambulacral area.

Eocidaris laevispina (Sandberger). Page 255.

Fig. 11. Middle Devonian, Villmar (after Bather, 1909, Plate 1, figs. 1–4). Enlarged. a, b, c, interambulacral plates; d, base of spine. a, the original of Sandberger's, 1855–'56, Plate 35, fig. 2b; b, the original of Sandberger's Plate 35, fig. 2; c, selected by Bather as the lecto-holotype, the original of Sandberger's Plate 35, fig. 2a; d, base of primary spine, the original of Sandberger's Plate 35, fig. 2d. None of the plates shows a basal terrace.

Fig. 12. Middle Devonian, Villmar (after Bather, 1909, Plate 1, fig. 5). Enlarged. The holotype of *Cidaris scrobiculata* Sandberger, here considered a synonym, the original of Sandberger's 1855–'56, Plate 35, fig. 3. No basal terrace.

Archaeocidaris koninckii Desor. Page 446.

Fig. 13. Lower Carboniferous, Tournay, Belgium (after Desor, 1858, Plate 21, figs. 7–10). Cotypes. Imperfectly known.

Archaeocidaris trautscholdi Tornquist. Page 448.

Fig. 14. Lower Carboniferous, Miatschkowa, near Moscow (after Tornquist, 1896, Plate 4, fig. 1). Holotype. Plate seen from within. Imperfectly known.

Archaeocidaris ladina Stache. Page 446.

Fig. 15. Bellerophonkalke, Lower Carboniferous, St. Martin, South Tyrol (after Stache, 1877, Plate 5, fig. 11b). Cotypes. Enlarged. Base of spine and pieces of spines with short spinules. Imperfectly known.

Echinocrinus striatus Eichwald. Page 450.

Fig. 16. Dolomitic Limestone, Bogoslowsk, Ural (after Eichwald, 1860, Plate 33, fig. 17). Holotype. Enlarged. Practically unrecognizable.

Fig. 1 drawn by A. T. Hollick; figs. 11, 12 copied by J. Henry Blake; all other figures copied by W. M. Barrows.

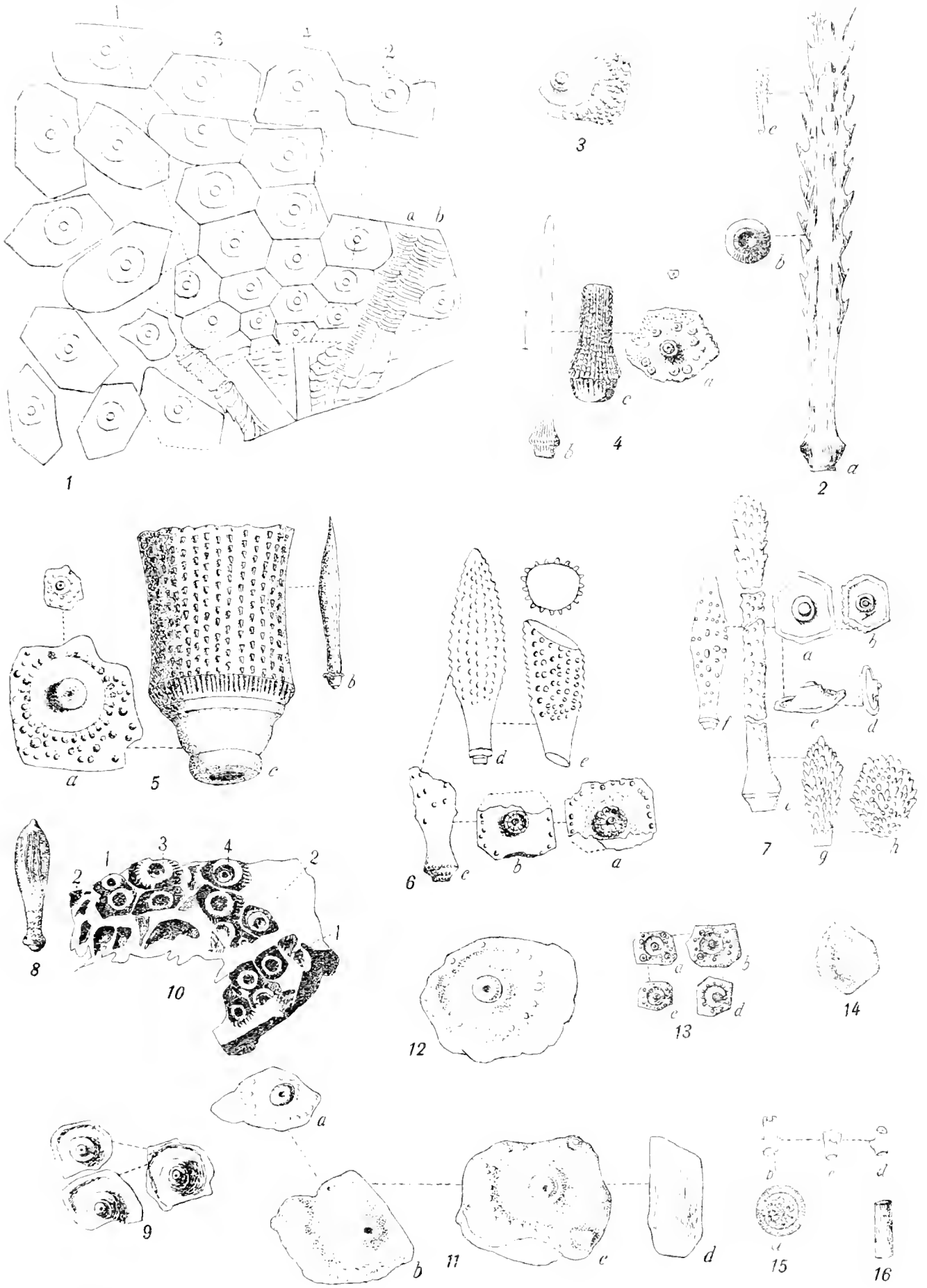
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PLATE 16.

Lepidocidaris squamosa Meek and Worthen. Page 282.

Fig. 1. Lower Burlington Limestone, Lower Carboniferous, Burlington, Iowa. Mus. Comp. Zoöl. Coll., 3,026. Holotype. Natural size. Every third ambulacral plate is higher than the intermediate plates; eight columns of interambulacral plates in area A. Drawings, Plate 17, figs. 1–5.

Fig. 2. Same horizon and locality, F. Springer Coll., 8,096. Natural size. Six columns of interambulacral plates in area A, primary spines in place. Drawings, Plate 17, figs. 7, 8, 10, 12, 14.

Fig. 3. Same horizon and locality, F. Springer Coll., 8,098. Natural size. Very clear for the surface characters of interambulacral plates.

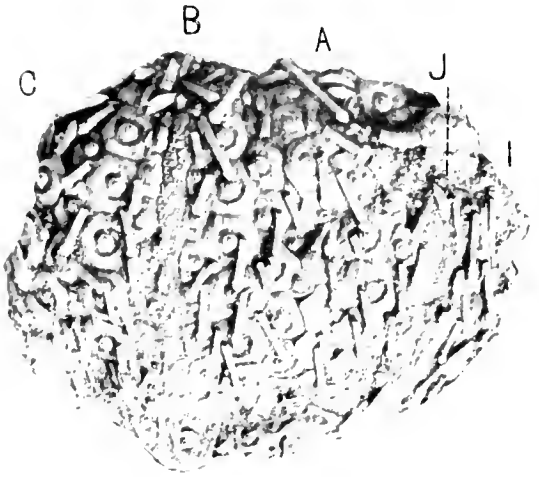
Echinocystites pomum Wyville Thomson. Page 252.

Fig. 4. Lower Ludlow, Silurian, Leintwardine, England, Museum of Practical Geology Coll., London, 7,385. (Original specimen of Sir Wyville Thomson's, 1861, Plate 3, fig. 3.) Cotype. Natural size. A ventral view, the outline of the ambulacral and interambulacral areas clearly defined. Tubercles and spines are visible on the interambulacra and an excellent lantern is in place.

Lepidocentrus drydenensis (Vanuxem). Page 288.

Fig. 5. Chemung Group, Upper Devonian, Dryden, New York. New York State Museum Coll., 4,200. Holotype. Natural size. The specimen is an internal mold of the ventral side, combined with some external features as spines. Drawings, Plate 21, figs. 1–3. On the same slab are additional incomplete impressions of other specimens of this species; these, with that figured, are the only known specimens of the species.

Fig. 4 from photograph by H. W. Tupper; figs. 2, 3, 5 by F. A. Saunderson; fig. 4 by J. W. Tutcher in London.



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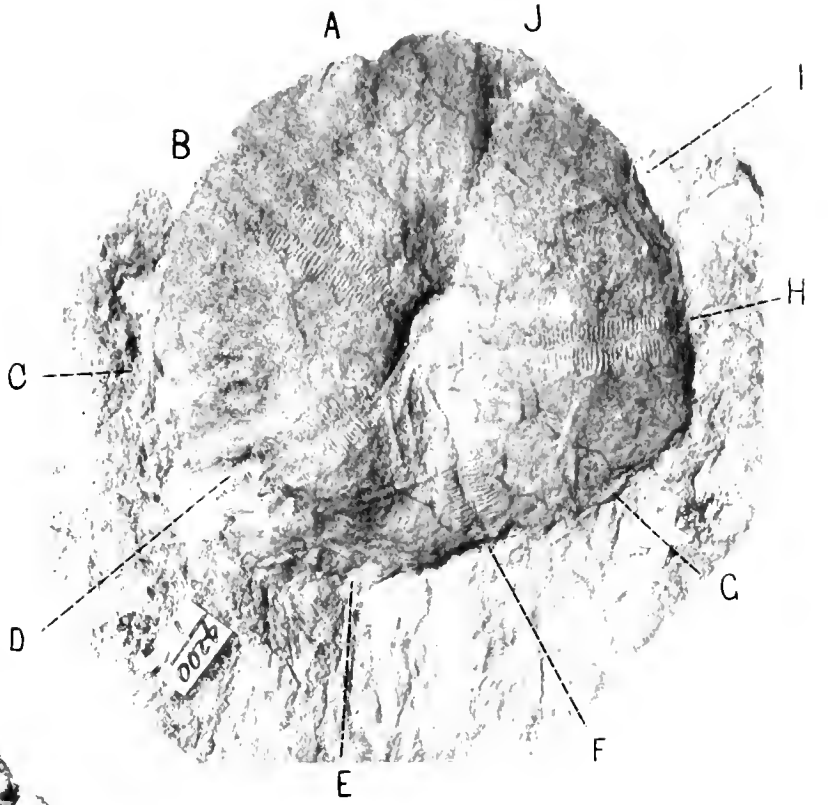

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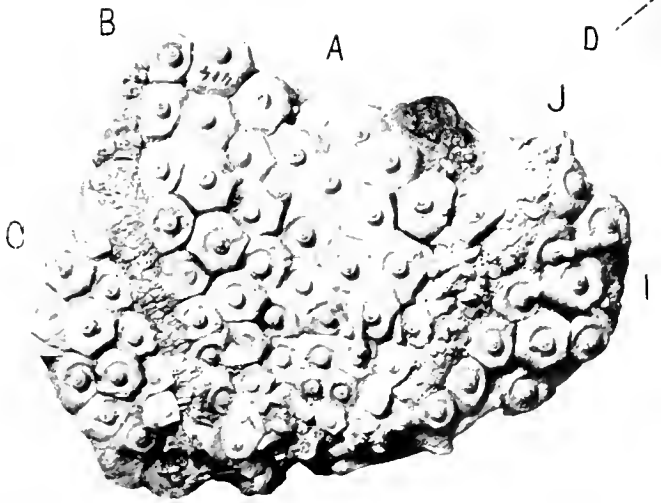

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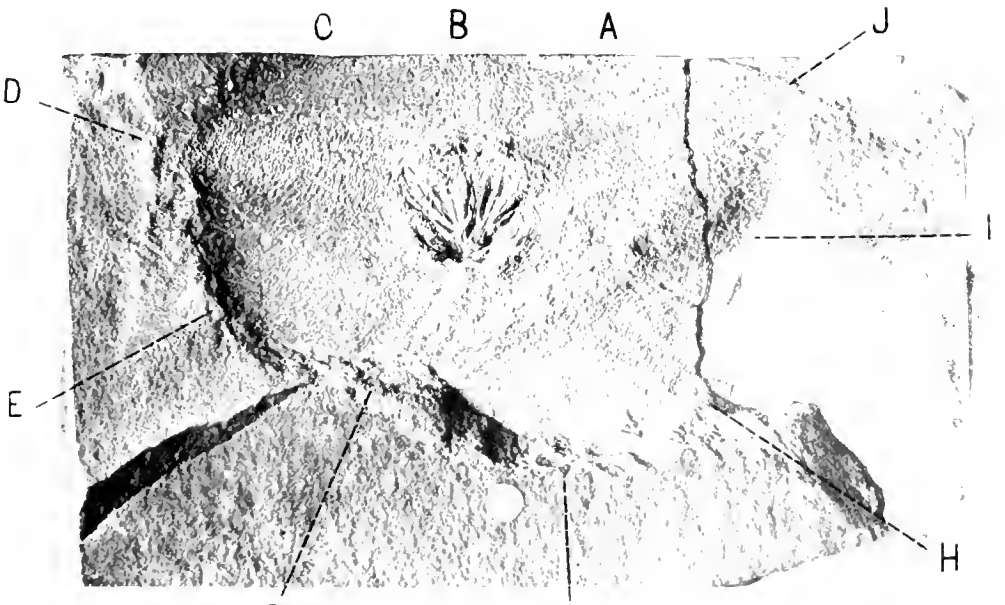

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F. A. SAUNDERSON, J. A. TUTCHER, H. W. TUPPER PHOTO. HELIOTYPE CO. BOSTON

PLATE 17.

Lepidocidaris squamosa Meek and Worthen. Page 282.

Figs. 1–14 Lower Burlington Limestone, Lower Carboniferous, Burlington, Iowa.

Figs. 1–5. Mus. Comp. Zoöl. Coll., 3,026 Same specimen as photograph, Plate 16, fig. 1. Holotype.

Fig. 1. × 0.9. Eight columns of interambulacral plates in area A, the seventh and eighth columns coming in below the mid-zone.

Fig. 2. Ambulacral detail from the area marked X in fig. 1. × 3.7. Every third ambulacral plate is wider and higher than the intermediate plates.

Fig. 3. Ambulacral detail from area marked XX in fig. 1, from nearer the mid-zone than is fig. 2. × 3.7. Every third plate higher and wider than the intermediate plates. In cases, some intermediate plates may be demi- or occluded instead of all plates being primaries. (Compare fig. 7.) Primary tubercles of interambulacral plate perforate, with wide scrobicule, but no basal terrace.

Fig. 4. Plates from the upper part of ambulacral area B to show beveling dorsally, and laterally under the interambulacrum. × 3.7.

Fig. 5. Dental pyramid. × 2. Epiphysis wanting; corrugations present for the attachment of the interpyramidal muscle.

Fig. 6. Mus. Comp. Zoöl. Coll., 3,046. × 2. Dental pyramid, face view, foramen magnum moderately deep; the sutural face for the epiphysis occurs on the left.

Fig. 7. F. Springer Coll., 8,096; same specimen as photograph, Plate 16, fig. 2. × 1.9. Every third ambulacral plate higher, wider, and apposed to two plates of the opposite half-area. Adradial plates are much narrower than interambulacral plates of the median columns

Fig. 8. Same specimen. × 7. Detail of typical ambulacral plates. A relatively high plate in one half-area is opposed to two lower plates of the opposite half-area.

Fig. 9. F. Springer Coll., 8,074. × 3.7. Interambulacrum with six columns of plates. There are four columns ventrally, the fifth and sixth columns coming in higher up. Ventrally there are some ambulacral plates which are evidently peristomal and in the middle line the tip of a tooth in place.

Fig. 10. Same specimen as fig. 7. × 3.7. Details of interambulacral plates with primary and secondary spines in place. There is no basal terrace around the primary tubercles; the lines in the figure that might be taken to indicate that structure are intended to represent the elevation of the boss.

Fig. 11. F. Springer Coll., 8,095. × 1.8. Six columns of plates in two interambulacral areas, adambulacral plates are narrower, primary spines in place.

Fig. 12. Same specimen as fig. 7, showing the character of ambulacral and interambulacral plates and the bases of primary spines. × 3.7.

Fig. 13. Mus. Comp. Zool. Coll., 3,046. × 1.9. Complete primary spines.

Fig. 14. F. Springer Coll., 8,096. Same specimen as fig. 7. × 3.6. Primary and secondary spines, showing their cylindrical character and fine vertical striae.

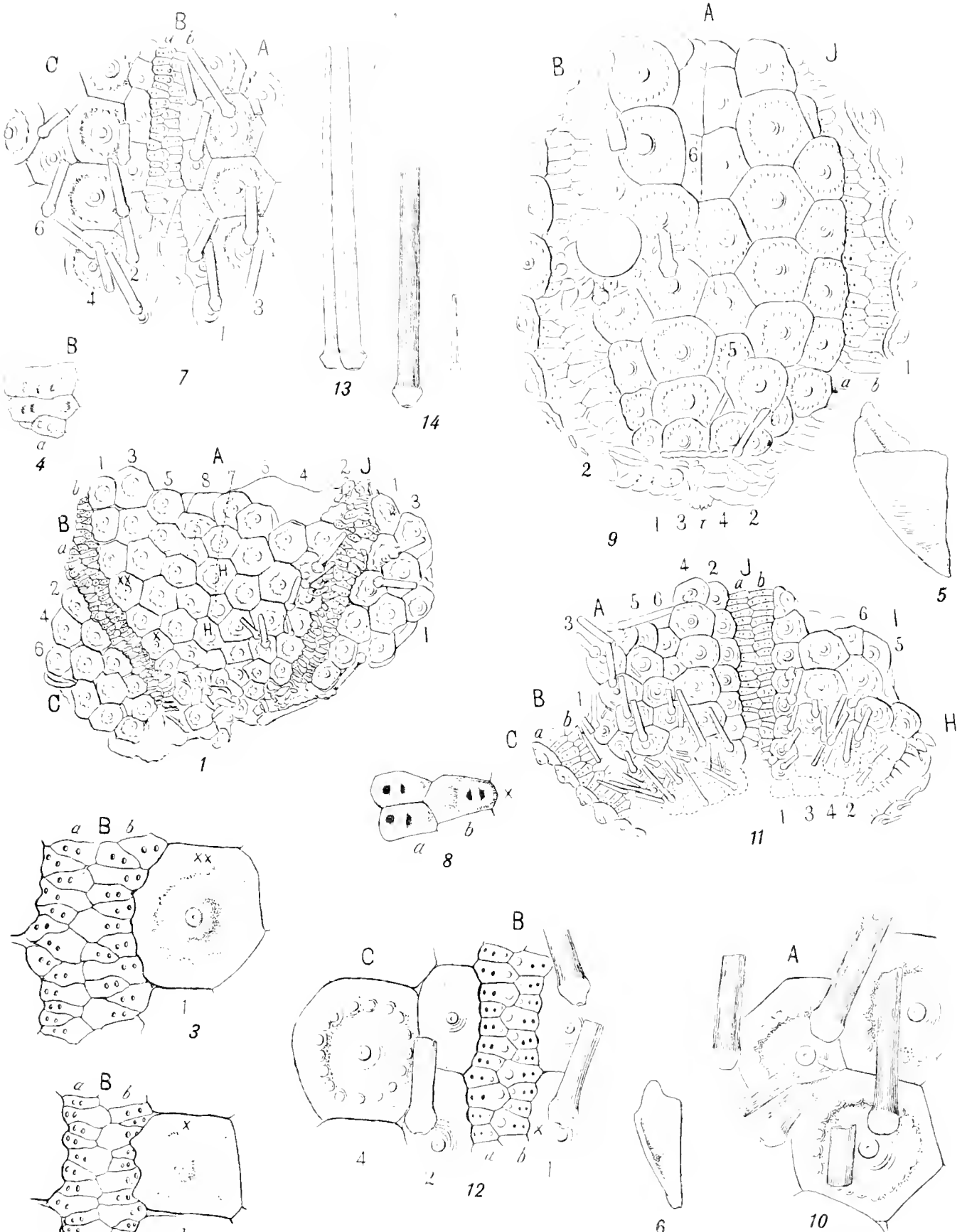

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PLATE 18.

Palaeodiscus ferox Salter. Page 250.

Fig. 1. Lower Ludlow, Silurian, near Ludlow, England. British Mus. Coll., E 1,255. × 3.7. An external sandstone mold of the ventral side. Ambulacra relatively broad ventrally; there are ambulacral pores ventrally as usual in Echini. Interambulacral plates irregular, faint in definition; impression of spines; and lantern in place in which latter can be discerned the impressions of braces and epiphyses.

Fig. 2. Lower Ludlow, Silurian, Church Hill, Leintwardine, England. British Museum Coll., E 1,252. × 3.7. An external sandstone mold of the ventral side. Ambulacral plates only on the peristome. Ambulacral plates in the corona have pore-pairs ventrally.

Fig. 3. Same specimen. Mold of the exterior. × 15. Ambulacral pores are in about the middle of each plate, fine spines on the interambulacral plate.

Fig. 4. Same specimen, impression of the interior. × 15. Shows ambulacral pores in the median line of each plate and a lateral extension of ambulacral plates beneath the interambulacral areas on either side.

Fig. 5. After Sollas, 1899, fig. 7, p. 702, enlarged. Dorsal view, showing compasses, braces, and epiphyses. Original in Oxford University Museum.

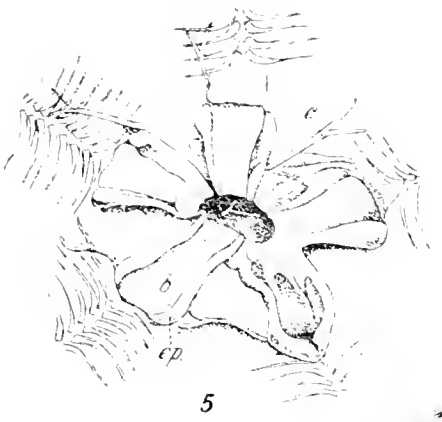
Echinocystites pomum Wyville Thomson. Page 252.

Fig. 6. Lower Ludlow, Silurian, Leintwardine, near Ludlow (after Gregory, 1897, Plate 7, fig. 1). × 0.9. Shows ambulacra and interambulacra with spines and a madreporite.

Fig. 7. After Gregory, 1897, fig. 1, p. 125. Ambulacral plates of a half-area, much enlarged.

Fig. 8. After Gregory, 1897, fig. 2, p. 125. Pyramid "seen from behind," enlarged.

Figs. 1–4 drawn from nature, and figs. 5, 6 copied by J. Henry Blake; figs. 7, 8 copied by W. M. Barrows.



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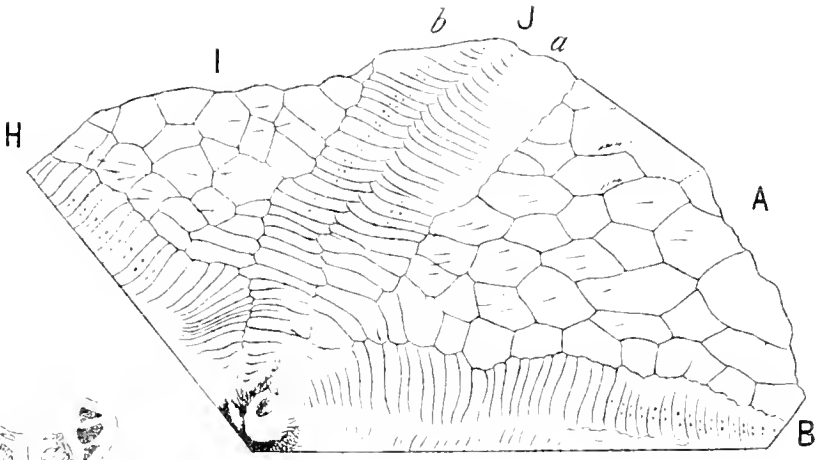

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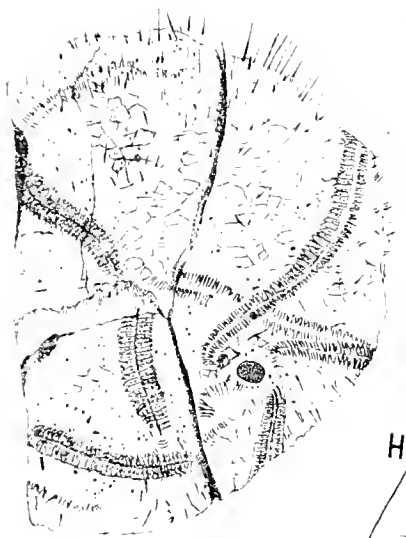

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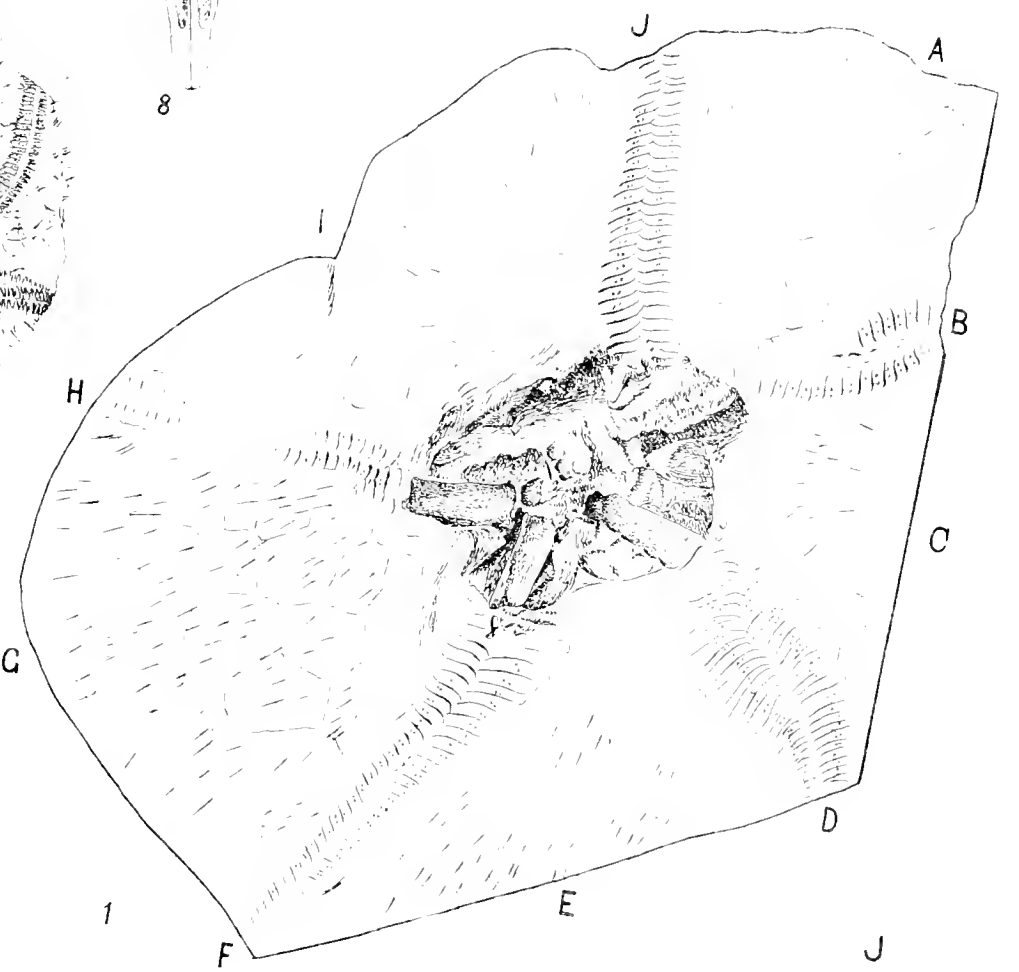

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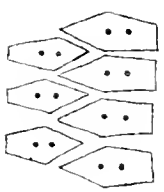

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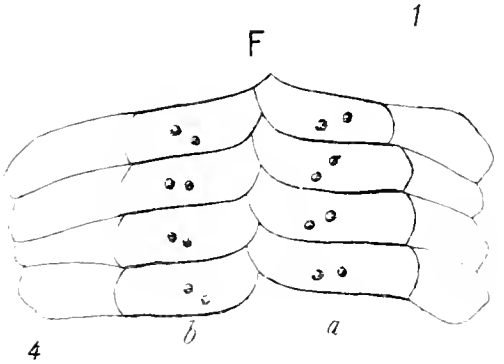

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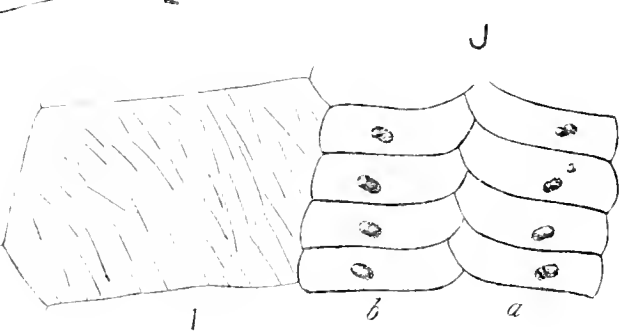

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PLATE 19.

Koninckocidaris silurica sp. nov. Page 285.

Fig. 1. From base of Rochester Shale, about ten feet above the Irondequot Limestone, Niagara Group, Upper Silurian, ravine of the Genesee River, northern part of Rochester, New York. A. W. Giles, collector, 1909. Rochester University Coll. Holotype. Natural size. Of special interest as by far the geologically oldest echinoid yet found in America. Test viewed from the interior, ambulacral plates are high, about three equaling the height of an adambulacral plate. Ambulacral plates bevel over the interambulacrals and imbricate dorsally, as this is an internal view. Pores are near the middle of the ambulacral area, a quite usual character of the interior. Eight columns of nearly rhombic plates in an interambulacral area, all of which extend to the apical disc. All interambulacral plates imbricate ventrally and toward the center, nearly covering column 7, which shows only as very narrow plates. This is because it is an internal view. (For imbrication and beveling of ambulacral and interambulacral plates seen from the interior and exterior, see text-figs. 32–37, p. 75.) Drawings, Plate 20, figs. 5, 6.

Lepidocentrus mülleri Schultze. Page 289.

Fig. 2. Middle Devonian, Muhlenberg, near Gerolstein, Prussia. Mus. Comp. Zoöl. Coll., 3,040 (from F. Schultze Coll.), holotype. Natural size. Ambulacra narrow, plates low. Interambulacrum A with 11 columns of nearly rhombic plates imbricating dorsally and from the center laterally. Columns 5, 6, 9, 10, and 11 of area A drop out dorsally. Drawings, Plate 20, figs. 8–10.

Fig. 3. Middle Devonian, Gerolstein, Prussia. Palaeontological Museum, Munich. Natural size. Interambulacral plates nearly rhombic, imbricating strongly; small primary and secondary tubercles and some spines in place. These two figs. (2, 3) are the most nearly complete specimens known in the species.

Fig. 4. A plate from the same specimen, to show a perforate eccentric primary tubercle with scrobicule and secondary tubercles. × 3.

Fig. 5. Same specimen. a, secondary spine, × 5, and b, primary spine, × 5; c, secondary spine, × 10. The spines are enlarged at the base, vertically very finely striate, nearly cylindrical as far as shown, but complete spines taper to a point distally.

Lepidocentrus whitfieldi sp. nov. Page 290.

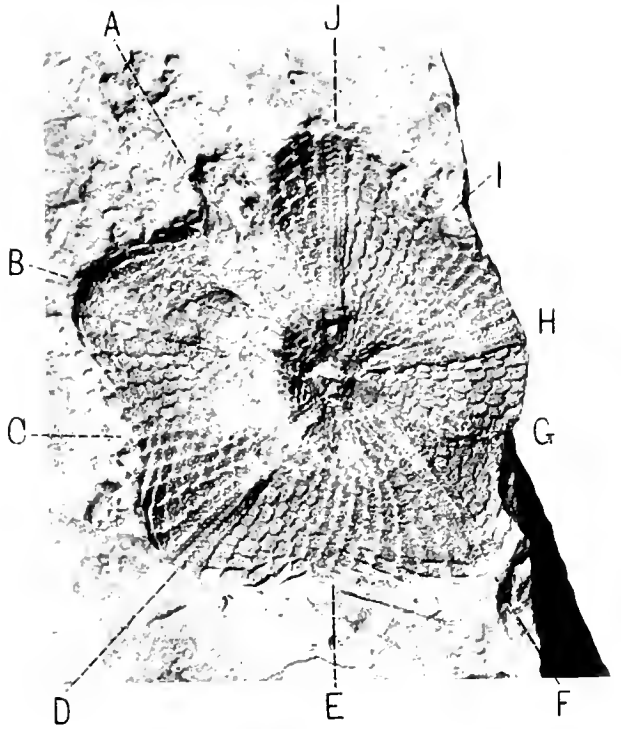
Fig. 6. Waverly Group, Lower Carboniferous, Licking County, Ohio. Amer. Mus. Nat. Hist. Coll., 6,391, holotype. Natural size. Ventral view, about spherical in form, but flattened ventrally, ambulacral areas narrow. Drawing, Plate 21, fig. 4.

Fig. 7. Same specimen, dorsal view. Drawing, Plate 21, fig. 5.

Hyattechinus pentagonus sp. nov. Page 295.

Fig. 8. Waverly Group, Lower Carboniferous, Meadville, Pennsylvania. Mus. Comp. Zool. Coll., 3,108 (from R. T. J. Coll.), paratype. Natural size. External sandstone mold of the dorsal side; ambulacra narrow, fourteen columns of plates in each interambulacrum. The apical disc measures about 9 mm. in diameter, and the test about 57 mm. in diameter. The apical disc therefore measures proportionately about 16 % of the diameter of the test.

Figs. 1, 2, 8 from photographs by H. W. Tupper; figs. 6, 7 by F. A. Saunderson; figs. 3–5 drawn by Anton Birkmaier.



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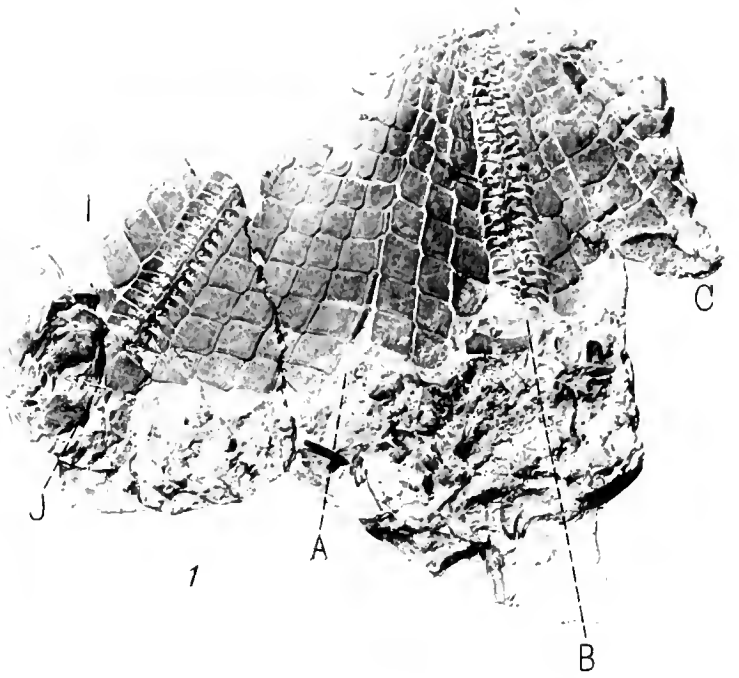

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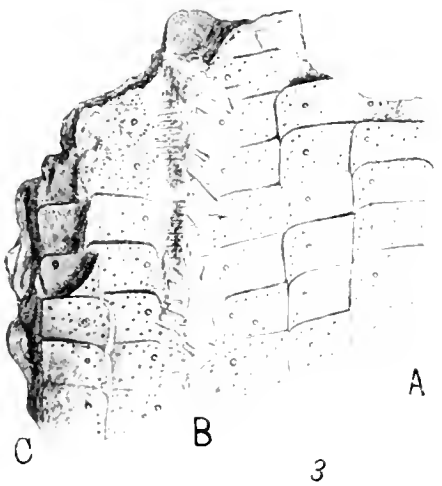

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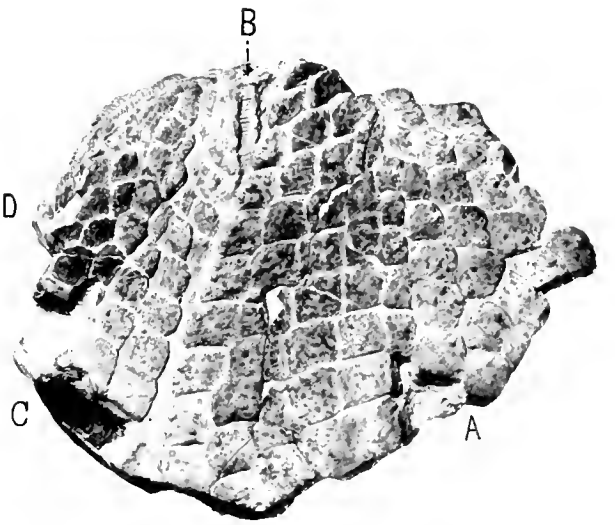

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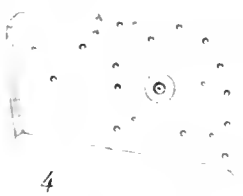

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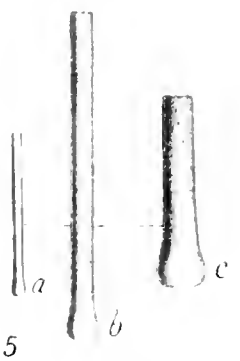

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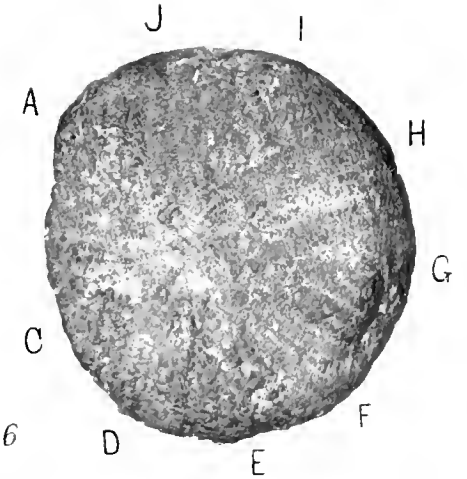

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PLATE 20.

Echinocystites pomum Wyville Thomson. Page 252.

Figs. 1–4. Lower Ludlow, Silurian, Leintwardine, England

Fig. 1. After Wyville Thomson, 1861, Plate 4, fig. 3. Cotype. × 0.9. Ambulacra narrow, the anal area (?) lies dorsally in an interambulacral area. Jaws and spines in place. (Compare Plate 16, fig. 4.)

Fig. 2. After Wyville Thomson, 1861, adapted from his Plate 4, fig. 2. Cotype. Enlarged. Impression of the exterior showing four columns of plates in an ambulacral area and associated interambulacral plates.

Fig. 3. After Wyville Thomson, 1861, Plate 4, fig. 3. Cotype. Much enlarged. A single interambulacral plate with a primary and secondary tubercles and a primary spine.

Fig. 4. British Museum Coll., E. 1,300. × 3.5. External mold, showing eight columns of plates in an interambulacral area, the width of an ambulacrum, also tubercles and spines.

Koninckocidaris silurica sp. nov. Page 285.

Fig. 5. Same specimen as photograph, Plate 19, fig. 1. Holotype. × 1.4. About three ambulacral plates equal the height of an interambulacral. Ambulacral plates bevel over the interambulacral and imbricate dorsally, as this is an internal view. Pores are near the middle of the ambulacral area, a usual character of the interior. Eight columns of nearly rhombic interambulacral plates in area A, all of which extend to the apical disc. All interambulacral plates imbricate ventrally and toward the center, nearly covering column 7. This is because it is an internal view. (Compare text-figs. 32–37, p. 75.) An ocular plate is in place capping ambulacrum B and the lateral borders of interambulacra A and C. Two genitals are in place, partially restored in C as indicated by dotted lines, and a few periproctal plates. A plate between ocular B and genital A may be a displaced periproctal plate. The apical disc is small.

Fig. 6. Same specimen, ambulacral plates of area J. × 3.6. An elevated T-shaped ridge is on each plate with pores on the ventral side of the same. An X in figs. 5 and 6 indicates the location of the plates figured in each.

Lepidocentrus rhenanus (Beyrich). Page 288.

Fig. 7. Devonian, Wippenfurth. Museum für Naturkunde Coll., Berlin. Holotype. × 0.9. The specimen is an internal mold. Ambulacral plates low, interambulacra with five columns in each area. In area E, the primordial interambulacral plate is in the basicoronal row; there are two plates in the second row, three in the third, and four in the fourth row, the fifth column coming in below the ambitus. Jaws present.

Lepidocentrus mülleri Schultze. Page 289.

Fig. 8. Same specimen as photograph, Plate 19, fig. 2. Holotype. × 0.9. Ambulacra narrow, plates low. Interambulacrum A with 11 columns of plates imbricating strongly dorsally and from the center laterally; several of the columns drop out, passing dorsally.

Fig. 9. Same specimen from the area marked X in fig. 8. × 3.6. Ambulacral plates showing the number against an interambulacral plate, the lateral position of pores and the beveling under interambulacral plates on the left.

Fig. 10. Same specimen, from the reverse side. × 3.6. Internal impression from near mid-zone. Pores in the center of each plate, ambulacral plates wider than on exterior, and interambulacral more angular than on exterior.

Fig. 11. Middle Devonian, Pelm, Prussia. Mus. Comp. Zoöl. Coll., 3,103 (from R. T. J. Coll.). × 1.7. Interambulacral plate from a left half-area, showing beveling, two primary tubercles with scrobicules and secondary tubercles.

Fig. 12. Same horizon, locality, and collection. × 1.7. Plate from a right half-area with one primary tubercle, the more usual character.

Fig. 13. Middle Devonian. Muhlenberg, near Gerolstein, Prussia (after Schultze, 1866, Plate 13, fig. 1b). Enlarged. Ambulacra narrow, plates low, pore-pairs uniserial and near the interambulacral suture.

Lepidocentrus eifelianus Müller. Page 291.

Fig. 14. Devonian, Rommersheim, Prussia (after Müller, 1857, Plate 3, fig. 1). Cotypes. × 0.9. Interambulacral plates showing surface characters and beveling.

Tornquistellus gracilis (Tornquist). Page 291.

Fig. 15. Lower Carboniferous, Hunsrucken, Prussia (after Tornquist, 1897, Plate 20, fig. 5). Holotype. × 0.9 and enlarged. Tubercles widely spaced, small primaries with scrobicular rings.

Fig. 7 from my sketch; figs. 13, 15 copied by W. M. Barrows; all others drawn by J. Henry Blake.

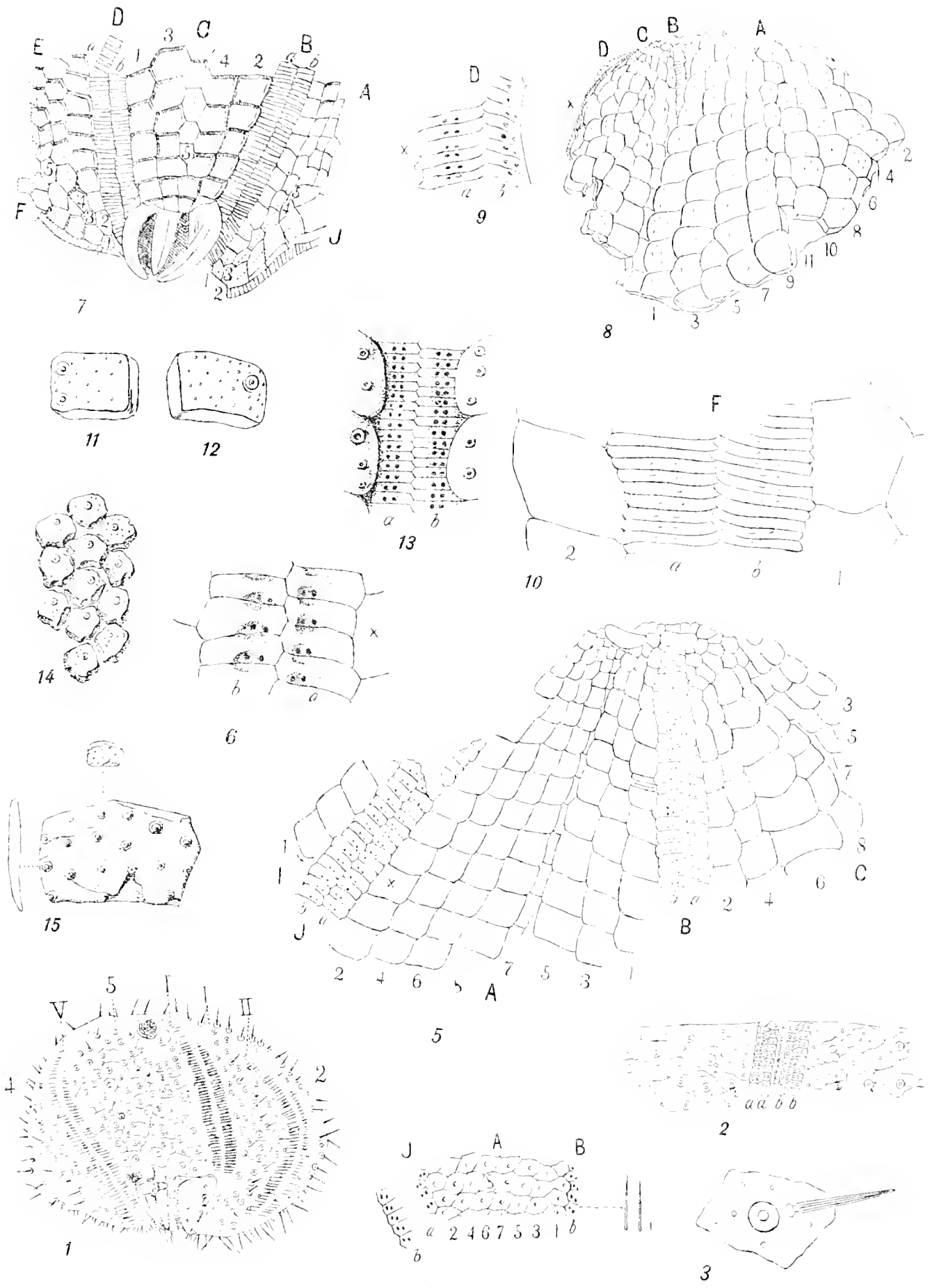
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PLATE 21.

Lepidocentrus drydenensis (Vanuxem). Page 288.

Fig. 1. Same specimen as photograph, Plate 16, fig. 5. Holotype. × 0.9. Internal mold with the superposed combination of some external characters. Ventral view, ambulacra are narrow, plates low. Interambulacral areas with apparently nine columns of plates which are ill defined as indicated by dotted lines, for the impression is weak. Acicular spines in place and also in the adjacent matrix, peristomal area small.

Fig. 2. Same specimen. × 3.6. Ambulacral plates with pores, from area D of fig. 1.

Fig. 3. Same specimen. × 3.6. Ambulacral plates from area B, showing the number apposed to an adradial plate. An X in figs. 1, 2, 3 indicates the location of the enlarged figures.

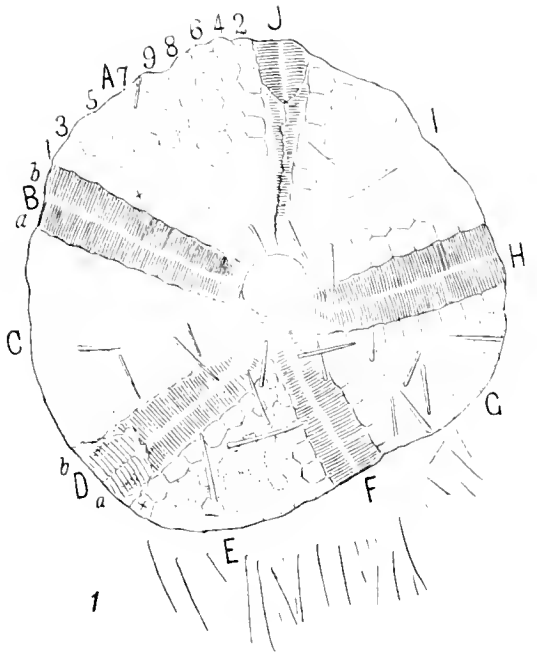
Lepidocentrus whitfieldi sp. nov. Page 290.

Fig. 4. Same specimen as photographs, Plate 19, figs. 6, 7. Holotype. × 1.8. Ventral view, internal mold. Ambulacra narrow, plates low. Eleven columns of interambulacral plates in an area. A primordial interambulacral plate is in place in the basicoronal row.

Fig. 5. Same specimen. × 1.8. Dorsal view, genital plates have numerous pores, ocular plates restored as indicated by dotted lines. The apical disc though incomplete is evidently small proportionately to the diameter of the test. This is the only specimen known in the genus Lepidocentrus which shows the plates of the apical disc (p. 287).

Hyattechinus rarispinus (Hall). Page 292.

Fig. 6. Waverly Group, Lower Carboniferous, Meadville, Pennsylvania. Amer. Mus. Nat. Hist. Coll., 6,392. Holotype. × 1.8. External sandstone mold of the dorsal side, so that the lettering is reversed. Ambulacra are narrow, plates low, eleven columns of interambulacral plates in each area, the eleventh introduced above the ambitus, columns 1 and 2 drop out dorsally. Same specimen as photograph, Plate 22, fig. 7. (See pp. 294, 395.)



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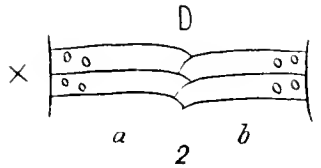

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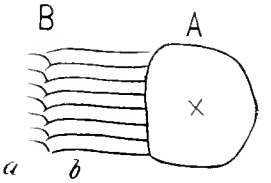

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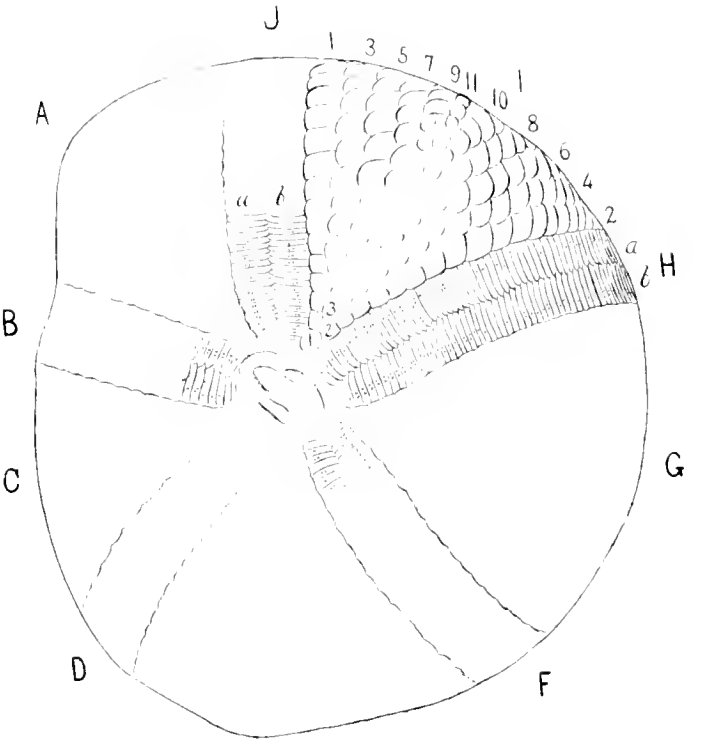

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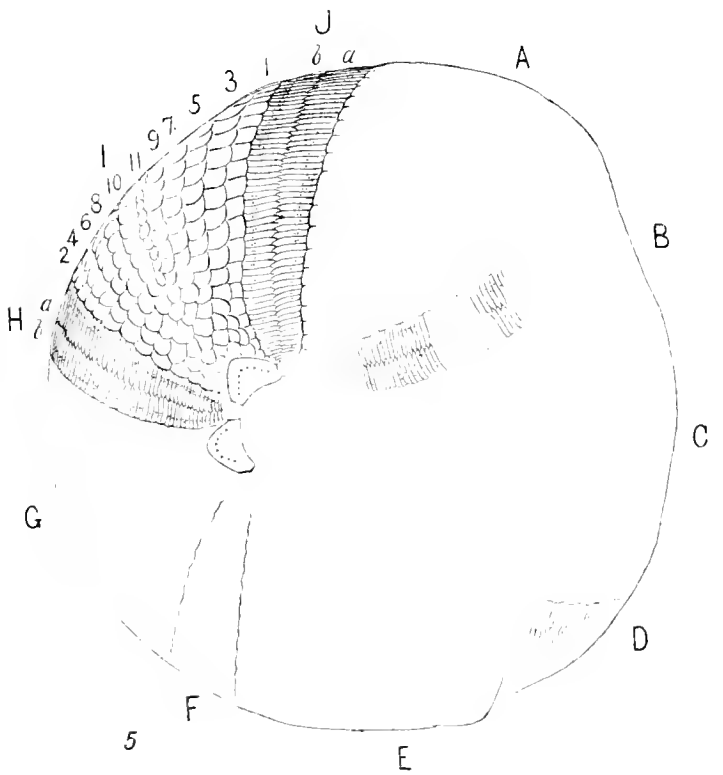

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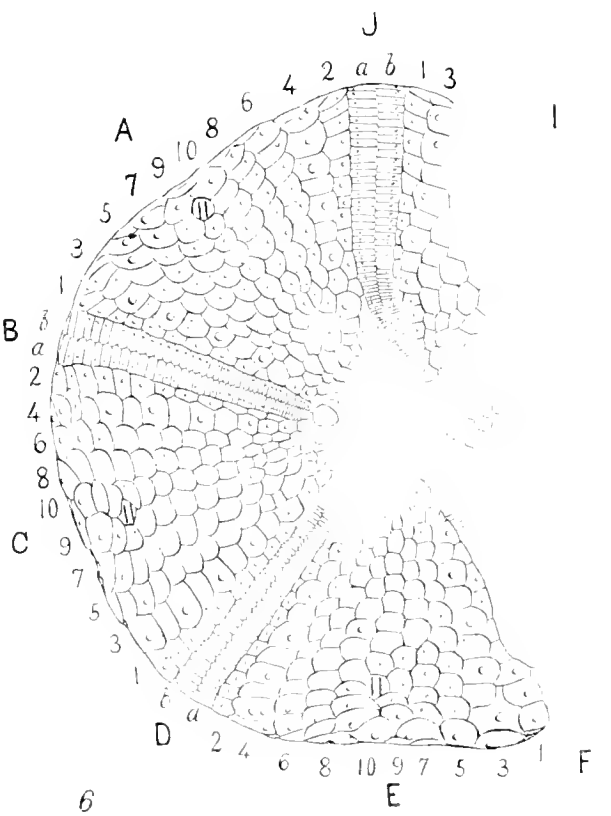

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Hyattechinus rarispinus Hall

Page 292.

Figs. 1–6, 8. Waverly Group, Lower Carboniferous, Warren, Pennsylvania; collected by the late Professor C. E. Beecher, and now in Yale University Museum.

Fig. 1. Yale Mus. Coll., 332. Natural size. External mold of the ventral side, and in areas B, C, and D in part an internal mold of the dorsal side. Ambulacra petaloid ventrally and narrow dorsally; the interambulacra all show a primordial interambulacral plate in the basicoronal row and a rapid introduction of succeeding columns of plates. Ambulacral plates only on the peristome. Tubercles are seen on the ventral portion, as that is an external mold; no tubercles on the portion that is dorsal, as that is an internal mold (pp. 21, 22). Drawing, Plate 23, fig. 4.

Fig. 2. Yale Mus. Coll., 333. Counterpart of the same specimen as fig. 4. Internal mold of the ventral side, and in areas A, B, C, and D in part, an external mold of the dorsal side. An impress of the lantern fills the oral area. Drawings, Plate 23, figs. 2, 7.

Fig. 3. Yale Mus. Coll., 329. Natural size. External mold of the ventral side, showing broad petaloid ambulacra, interambulacra with tubercles, and in places spines impressed in the mold. The peristome is covered with ambulacral plates only.

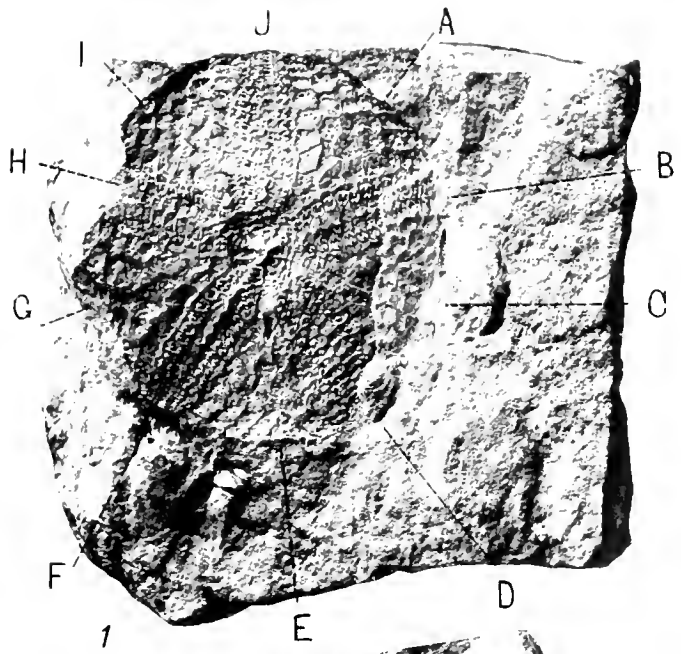
Fig. 4. Yale Mus. Coll., 328. Counterpart of the same specimen as fig. 3. External mold of the dorsal side. Ambulacra narrow, interambulacra with tubercles and a general impression of the dorsal face of the lantern, caused by the flattening of the test.

Fig. 5. On the same slab as fig. 3. Yale Mus. Coll., 329. External mold of the ventral side, showing in part structures as in fig. 3. Drawing, Plate 23, fig. 6.

Fig. 6. Counterpart of same specimen as fig. 5. Yale Mus. Coll., 328. External mold of the dorsal side, showing in part structures as in fig. 4.

Fig. 7. Waverly Group, Lower Carboniferous, Meadville, Pennsylvania. Amer. Mus. Nat. Hist. Coll., 6,392. Holotype. Natural size. External sandstone mold of the dorsal side. Ambulacra narrow, plates low, eleven columns of plates in each interambulacral area (pp. 294, 395). Drawing, Plate 21, fig. 6.

Fig. 8. Yale Mus. Coll., 325. Natural size. External mold of the dorsal side. Ambulacral areas narrow, interambulacra with 11 columns of plates in areas A and G, 12 columns of plates in area 1, or 13 columns of plates in areas C and E; tubercles prominent; a general impression exists of the top of lantern, caused by the flattening of the test. Drawing, Plate 23, figs. 3, 1. On the reverse side of this slab are more or less complete impressions of seven other specimens of the same species, showing that it was common in the locality.



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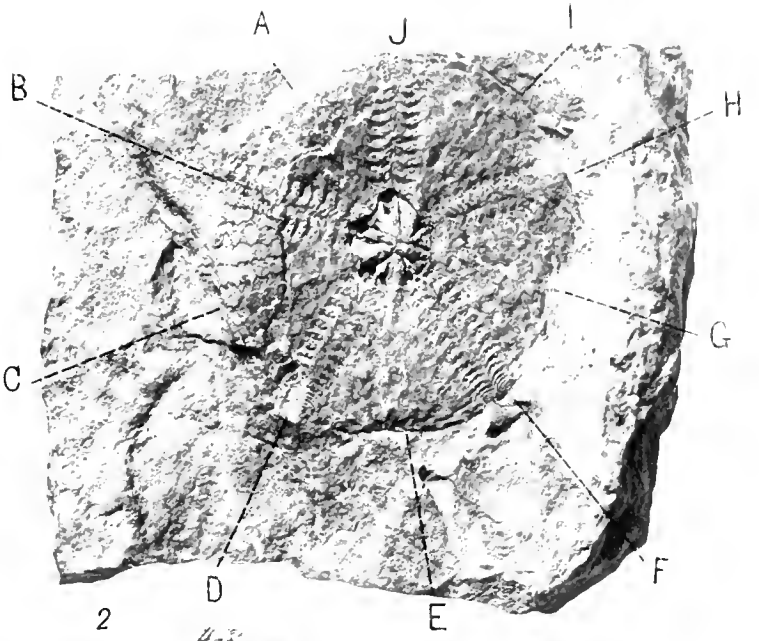

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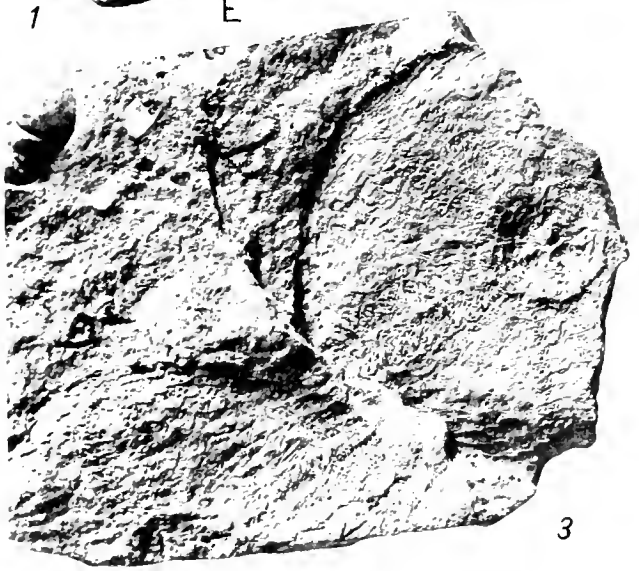

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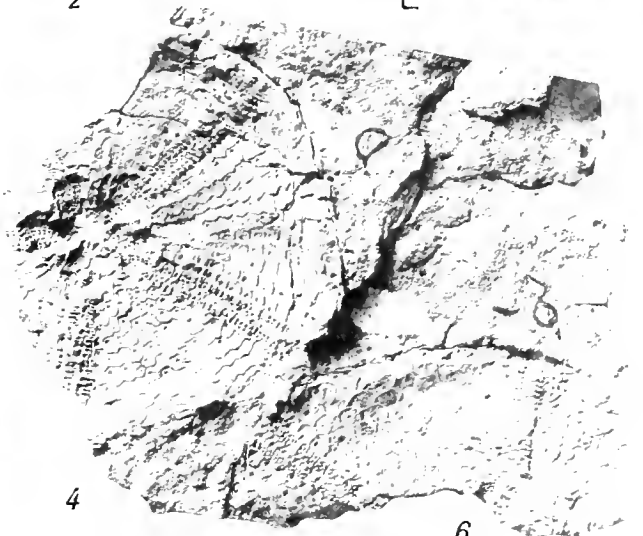

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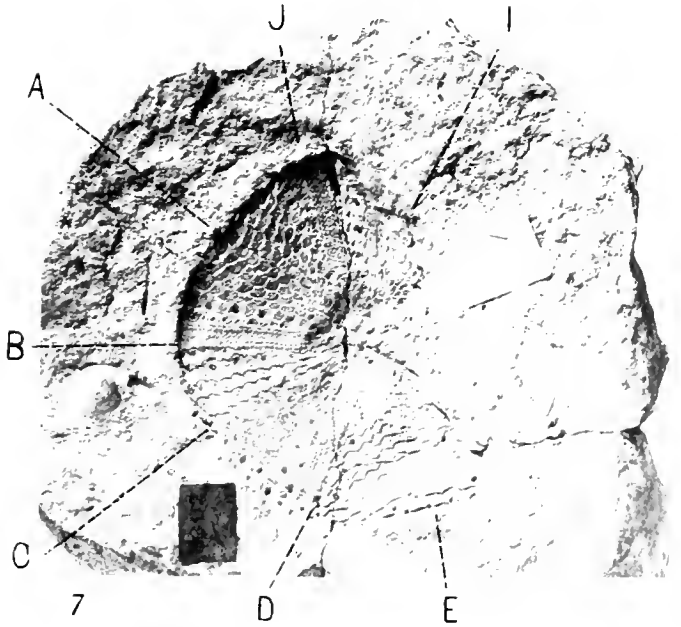

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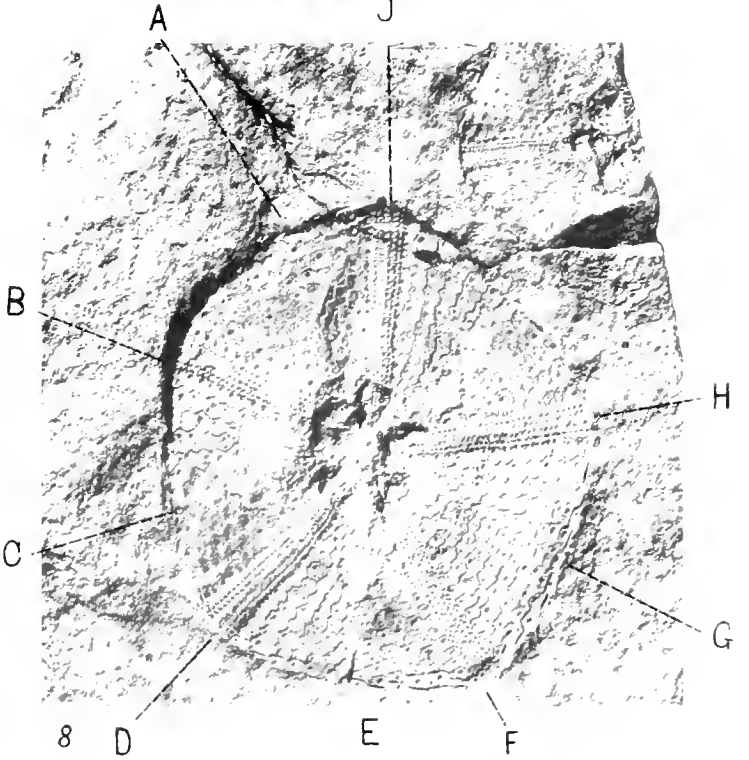

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F. A. SAUNDERSON, PHOTO.

HELIOTYPE CO. BOSTON.

JACKSON ON ECHINI.

PLATE 23.

Hyattechinus rarispinus (Hall). Page 292.

Figs. 1–7. Waverly Group, Lower Carboniferous, Warren, Pennsylvania, collected by the late Professor C. E. Beecher; all are in Yale University Museum.

Fig. 1. Yale Mus. Coll., 332. × 1.9. Same specimen as photograph, Plate 22, fig. 1. External mold of the ventral side and in areas B, C, and D in part, an internal mold of the dorsal side. Ambulacra broad, petaloid ventrally, pore-pairs uniserial. Interambulacra very clear; the primordial interambulacral plates are in the basicoronal row, two plates in the second row, three in the third, four plates in the fourth row, and so on, the columns coming in very rapidly, showing a highly accelerated development. The peristome is covered with many rows of low ambulacral plates only (pp. 81, 213). In areas B, C, and D there exists in part an internal mold of the dorsal side; these plates therefore have no tubercles. The ambulacral plates here are lower than they are ventrally and the areas are markedly narrower.

Fig. 2. Yale Mus. Coll. 333. Same specimen as photograph, Plate 22, fig. 2. × 2.7. Internal mold of the ventral side. Ambulacral plates show pore-pairs as elevated plugs, also pits near the median line, which are molds of spinose elevations extending proximally from the ambulacral plates. (Compare Plate 3, figs. 12, 13; p. 61.) Primordial interambulacral plates are in the basicoronal row. In the center the mold of the lantern represents interradially casts of the five alveolar cavities (each of which was enclosed by two half-pyramids); radially, casts of the spaces between the half-pyramids, which in life were occupied by the interpyramidal muscles (compare Plate 5, fig. 2). The lantern itself is quite absent.

Fig. 3. Yale Mus. Coll., 325. × 1.6. Same specimen as photograph, Plate 22, fig. 8. External mold of the dorsal side. Ambulacra are narrow, plates low. Interambulacral areas with 11 columns of plates in areas A and G, 12 columns of plates in area I, and in two areas, C and E, 13 columns of plates (p. 50); part of the columns, notably 1 and 2, drop out dorsally as a senescent character. Primary and secondary tubercles exist as sunken impressions.

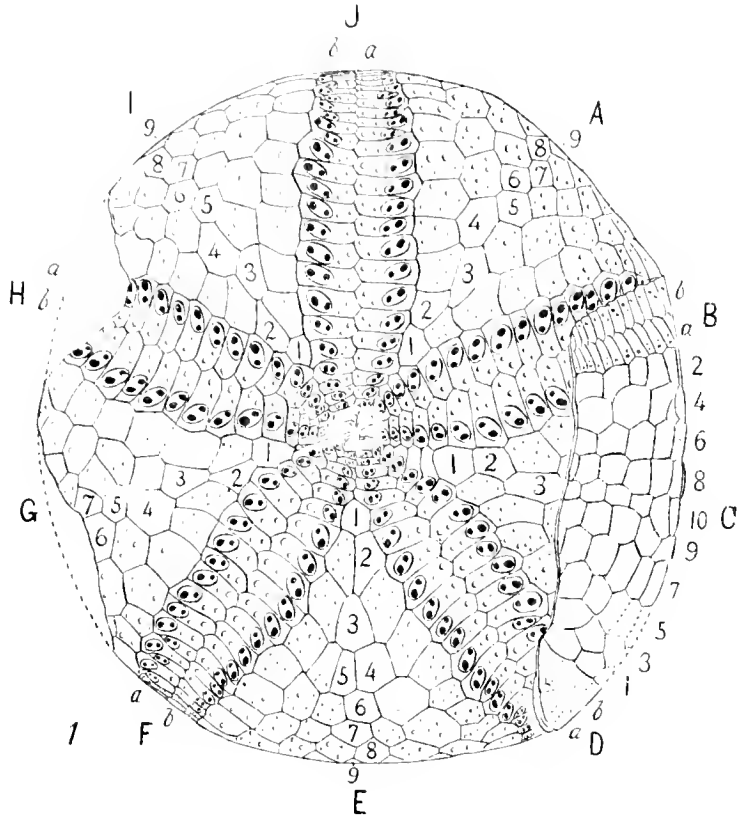
Fig. 4. Same specimen. Yale Mus. Coll., 325. × 3.7. Ambulacral detail enlarged; from the point marked X in fig. 3. Pore-pairs are in peripodia.

Fig. 5. Yale Mus. Coll., 327. External mold of a fragment of the dorsal side. × 5. Primary and secondary tubercles on interambulacral plates.

Fig. 6. Yale Mus. Coll., 329. Same specimen as Plate 22, fig. 5. × 5. External mold of the ventral side with spines in place.

Fig. 7. Yale Mus. Coll., 333. × 2. Same specimen as photograph, Plate 22, fig. 2. × 1.9. Internal mold of the ventral side, showing pore-pairs existent as plugs, also pits which represent elevated spine-like processes on the proximal face of the ambulacral plates. (Compare Plate 3, figs. 12, 13; Plate 24, fig. 6; p. 61.)

As the figures on this plate are all from drawings of external or internal sandstone molds, the orientation and lettering are reversed from what they would be if taken from external or internal views of a test (pp. 20, 22).



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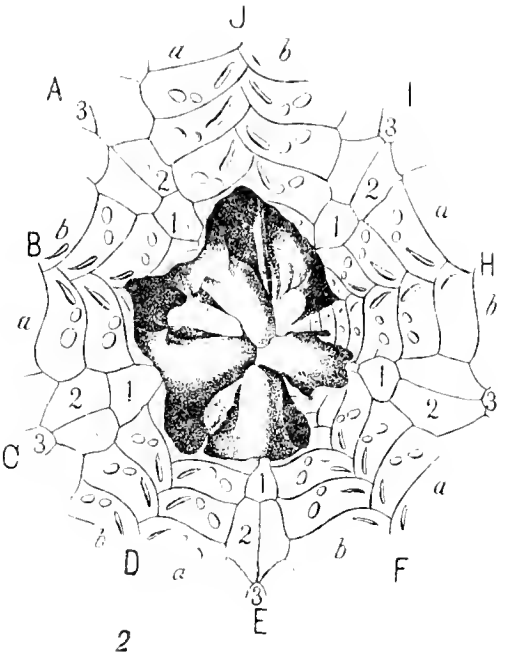

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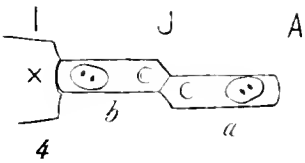

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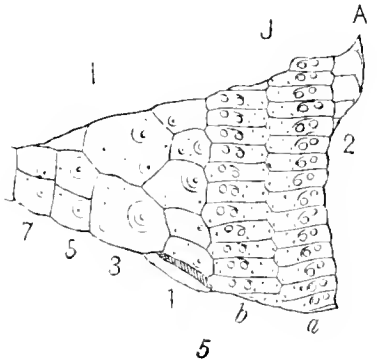

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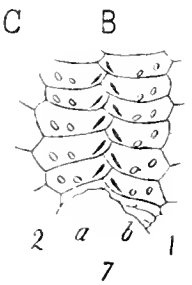

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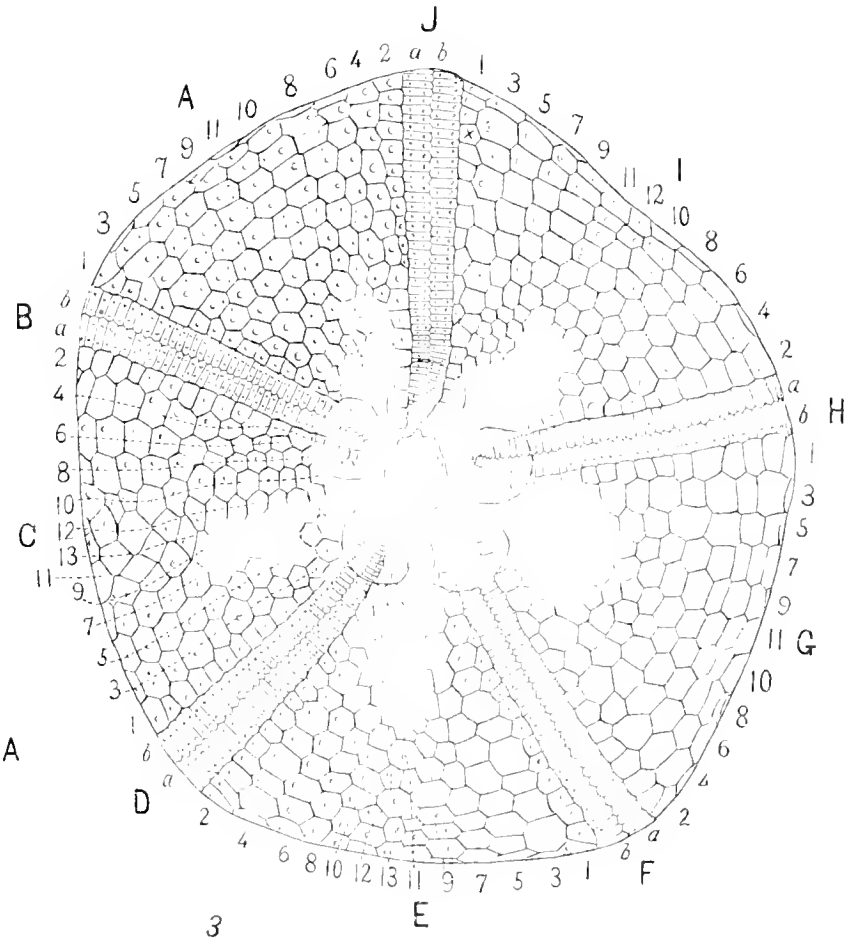

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PLATE 24.

Hyattechinus pentagonus sp. nov. Page 295.

Figs. 1–4. Waverly Group, Lower Carboniferous, Meadville, Pennsylvania.

Fig. 1. Alleghany College Coll. Holotype. Natural size. External mold of the dorsal side. The test is strongly pentagonal in outline; ambulacra are narrow, interambulacra broad, each with 14 columns of plates in each area, genital and ocular plates in place. The apical disc is small, being proportionately about 16% of the diameter of the test. Drawings, Plate 25, figs. 3, 4.

Figs. 2, 3. Similar external molds of the dorsal side of two other specimens of the same species and on the same slab. Paratypes.

Fig. 4. Mus. Comp. Zoöl. Coll., 3.107 (from R. T. J. Coll.). Paratype. Natural size. External mold of the ventral side. Ambulacra broad, petaloid. Primordial interambulacral plates in the basicoronal row; additional columns of plates come in with a very accelerated development. Drawing, Plate 25, fig. 1.

Hyattechinus beecheri sp. nov. Page 297.

Figs. 5–8. Waverly Group, Lower Carboniferous, Warren, Pennsylvania. Obtained by the late Professor C. E. Beecher from the late Dr. Randall, who collected it; now in Yale Univ. Mus. Coll., 323. Holotype. Natural size. Bilaterally symmetrical through an ambulacrum and opposite interambulacrum, which I consider as the axis III, 5, a unique character in regular Echini (p. 32). The specimen is an internal mold representing an impress of the inner side of the plates, but so nearly perfect, that it is represented spread out in Plate 26.

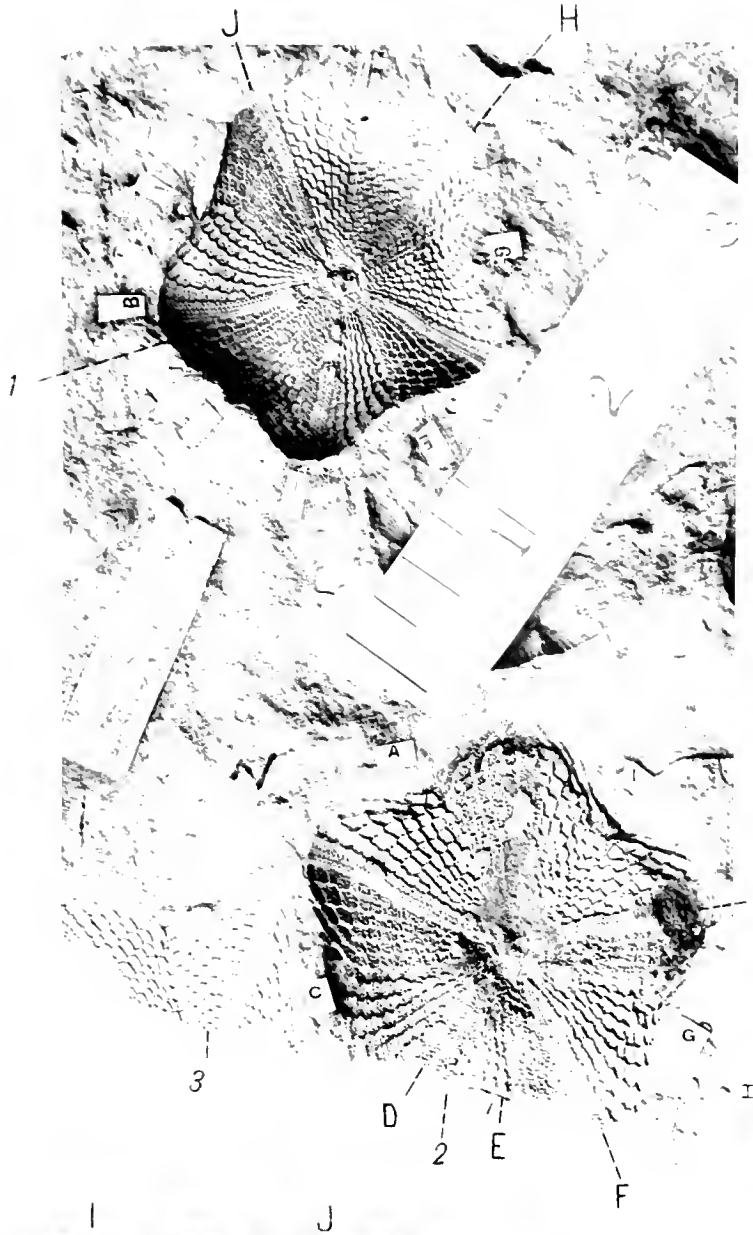
Fig. 5. Ventral view. Natural size. Ambulacra broad, petaloid, ambulacral pores represented by elevated plugs. In addition, each plate ventrally bears a reëntrant elongate pit which represents the impression of an elevated spine-like process on the inner face of the plates, seen best in areas III and IV. Primordial interambulacral plates are in the basicoronal row and additional interambulacral columns come in rapidly, the full number being attained at or just above the ambitus.

Fig. 6. Drawn from a wax cast of the ventral side which therefore represents the internal face of the ventral plates. ×3.7. The pore-pairs exist as pits and the spine-like elevated processes stand up as ridges; from the area indicated by X in Plate 26. (Compare Plate 3, figs. 12, 13; p. 61.)

Fig. 7. Side view, in profile. Natural size. The test is apparently of the original form and height.

Fig. 8. Dorsal view. Natural size. Ambulacra narrow, plates low, the impressions of the genital and some periproctal plates are in place. The apical disc is small proportionately to the length of the test. This specimen is shown spread out in Plate 26, and the apical portion is shown in Plate 25, fig. 5.

Figs. 1–3 photographed by H. W. Tupper; other photographs by F. A. Saunderson; the drawing, fig. 6, by J. Henry Blake.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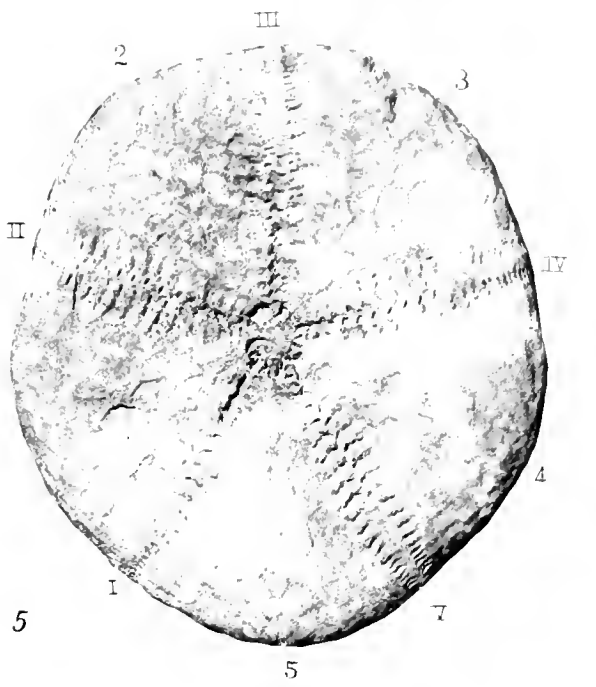
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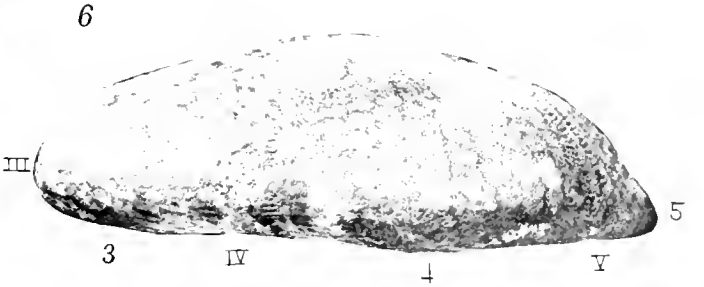
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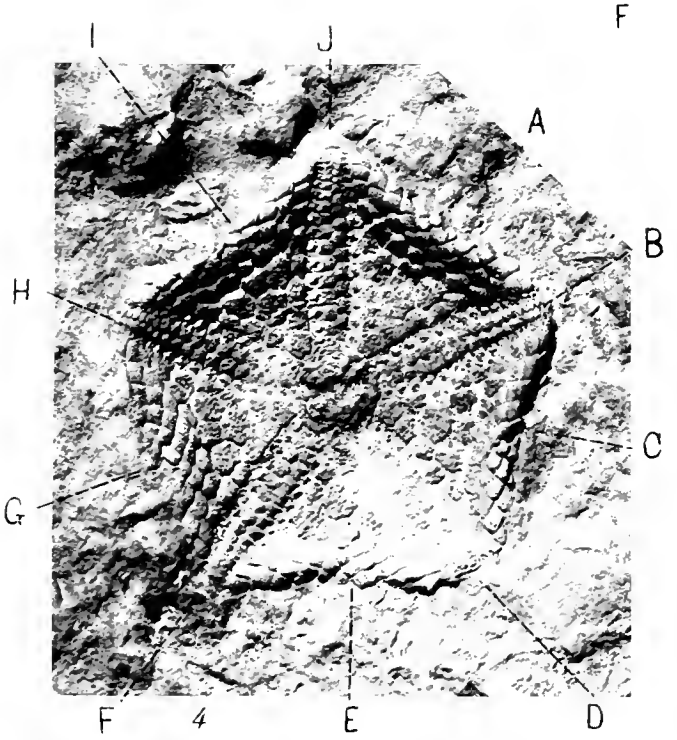
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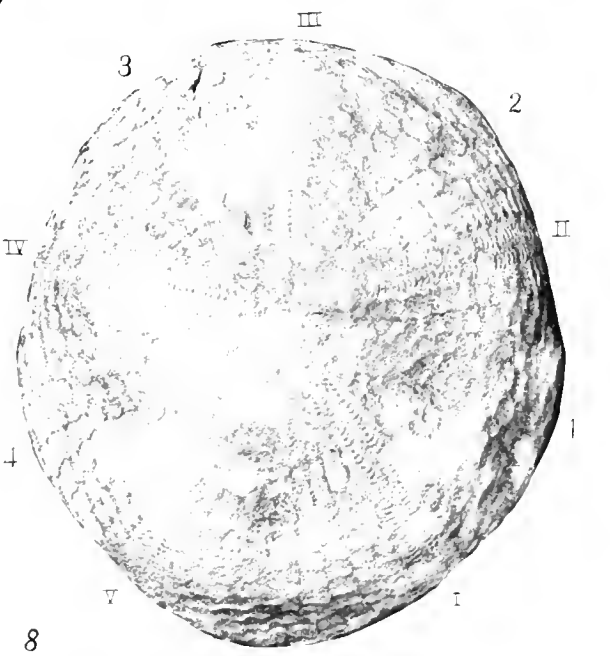
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PLATE 25.

Hyattechinus pentagonus sp. nov. Page 295.

Figs. 1–4. Waverly Group, Lower Carboniferous, Meadville, Pennsylvania; all external sandstone molds.

Fig. 1. Mus. Comp. Zoöl. Coll., 3,107 (from R. T. J. Coll.). Paratype. × 1.8. External mold of the ventral side, the same specimen as photograph, Plate 24, fig. 4. Ambulacra broad, petaloid; pore-pairs uniserial with clearly defined peripodia. Interambulacra in each area have the primordial plate in the basicoronal row; there are two plates in the second row and three plates in the third row, dorsal to which new columns are added with great rapidity, indicating a very accelerated development, eleven columns being attained before reaching the ambitus. The peristome, as far as preserved, has ambulacral plates only. The plates are partially restored in areas D and E, as indicated by dotted lines.

Fig. 2. Same specimen. × 7. Enlarged to show detail of ambulacral plates. Pore-pairs in peripodia from the area marked X in fig. 1.

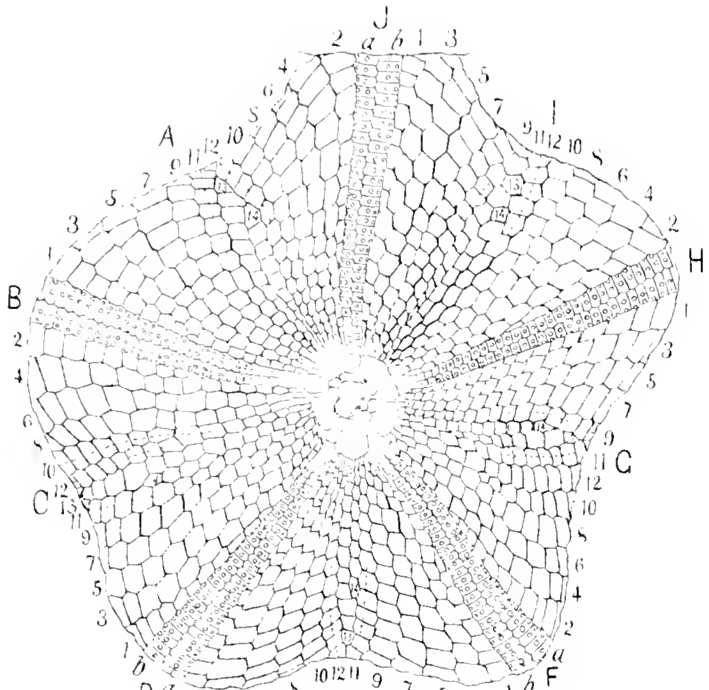
Fig. 3. Alleghany College Coll. Holotype. × 1.8. Dorsal view. Same specimen as photograph, Plate 24, fig. 1. Ambulacra narrow, marking the limits of the pentagon radially. Interambulacra with 14 columns of plates in each area, the highest number known in any sea-urchin. The 13th and 14th columns originate above the ambitus. In area C there are only four plates in column 14. Columns 1 and 2 and some additional columns drop out before reaching the apical disc. Four of the genital and ocular plates and a few periproctal plates are in place dorsally. The apical disc is small, measuring proportionately about 16 % of the diameter of the test. Remarkably clear for a sandstone mold.

Fig. 4. Same specimen. Holotype. × 3.6. Enlargement to show the dorsal structure of one interambulacrum. Columns 1, 2, 10, and 13 drop out before reaching apical disc.

Hyattechinus beecheri sp. nov. Page 297.

Fig. 5. Yale Mus. Coll., 323. Same specimen as photograph, Plate 24, fig. 8 and Plate 26, fig. 1. Holotype. × 3.6. Shows genital, ocular, and periproctal plates. The oculars and in part the genital and periproctal plates are restored, as indicated by dotted lines. All of these plates are represented by impressions only as the specimen is an internal sandstone mold. The genital pores are not indicated as they were not seen in the specimen.

Figs. 3 and 4 drawn by J. H. Emerton; figs. 1, 2, 5 by J. Henry Blake.



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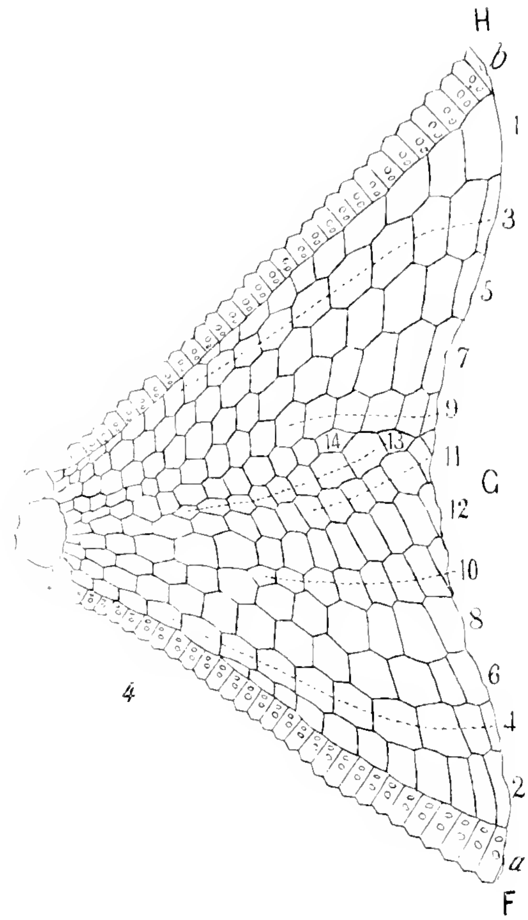

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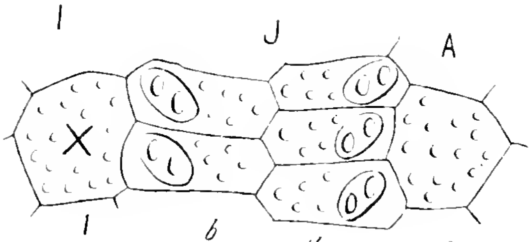

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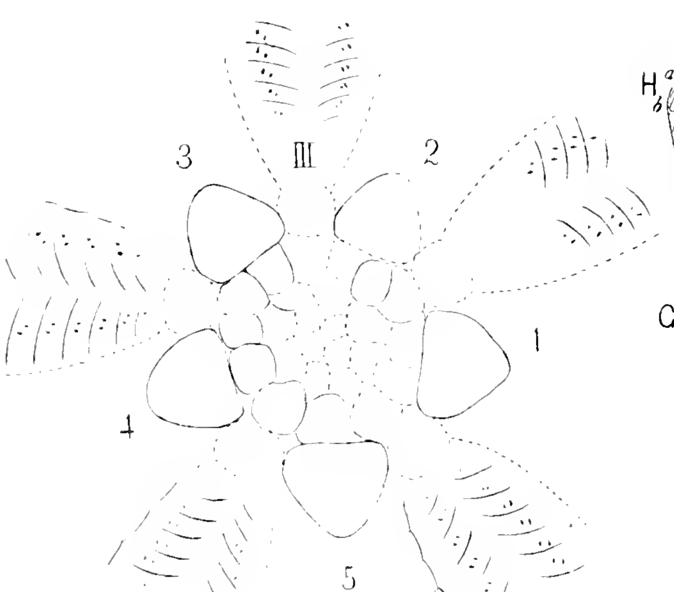

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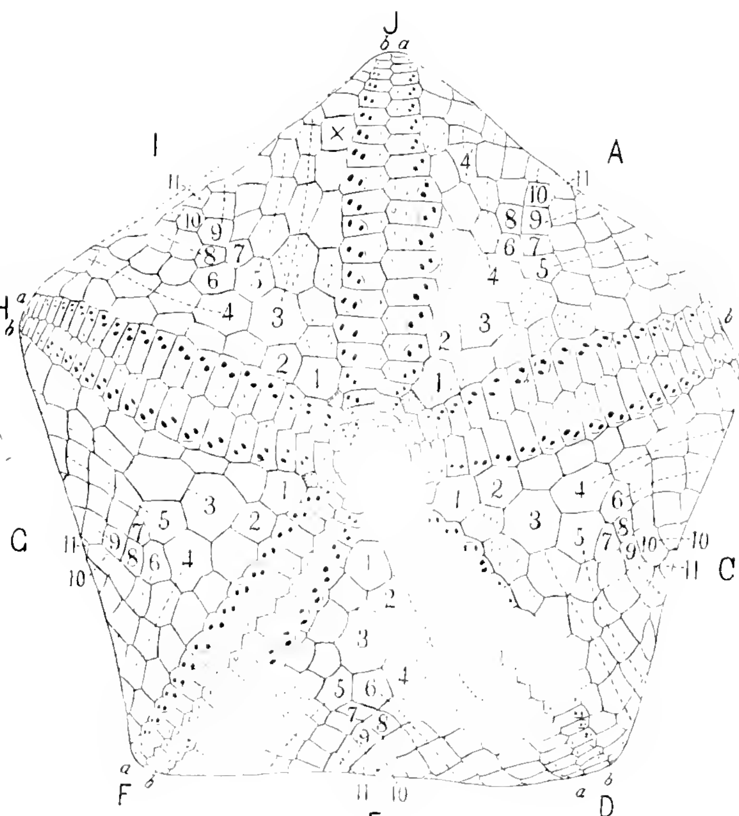

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JACKSON ON ECHINI

PLATE 26.

Hyattechinus beecheri sp. nov. Page 297.

Fig. 1. Yale Mus. Coll., 323, holotype. Same specimen as photographs, Plate 24, figs. 5, 7, 8, and Plate 25, fig. 5. × 1.1
This unique specimen, though a sandstone mold of the interior, bears the impress of plates so that it can be drawn spread out by the Lovén method with very few gaps, part of which are filled in as plates with dotted lines in areas 3, 4, and 5. The gaps of the interambulacra laterally at the ambitus are due to the mechanical requirements in making the drawing. This is the only regular sea-urchin known that is bilaterally symmetrical through an ambulacrum and posterior interambulacrum, and the orientation is based on this bilateral symmetry.

Ambulacra broad, petaloid ventrally, narrow dorsally. Ambulacral plates ventrally near the median suture have a series of pits caused by elevated spinose processes on the proximal face of the plates (Plate 24, fig. 6; compare Plate 3, figs. 12, 13; p. 61). Interambulacra have each 11 columns of plates. The primordial interambulacral plates are in the basicoronal row in each area; there are two plates in the second row, three in the third, and four in the fourth row, each indicating the introduction of a newly added column. Column 5 originates in the fifth row in areas 1, 5, and 4, but not until the sixth row in areas 2 and 3. The sixth column originates in the sixth row in areas 1, 5, and 4, but not until the eighth row in areas 2 and 3. This seems to accord with the bilateral symmetry, the posterior interambulacral trivium developing more quickly than the anterior interambulacral bivium. After the sixth, the succeeding columns come in with great rapidity, practically a new column being added in each row of each area until the full number is attained at or near the ambitus. Dorsally, columns 1 and 2 and some additional columns in each area drop out before reaching the apical disc. The peristome as far as indicated is covered with ambulacral plates only, and the lantern is represented by casts of the alveolar cavities and inner faces of the teeth.

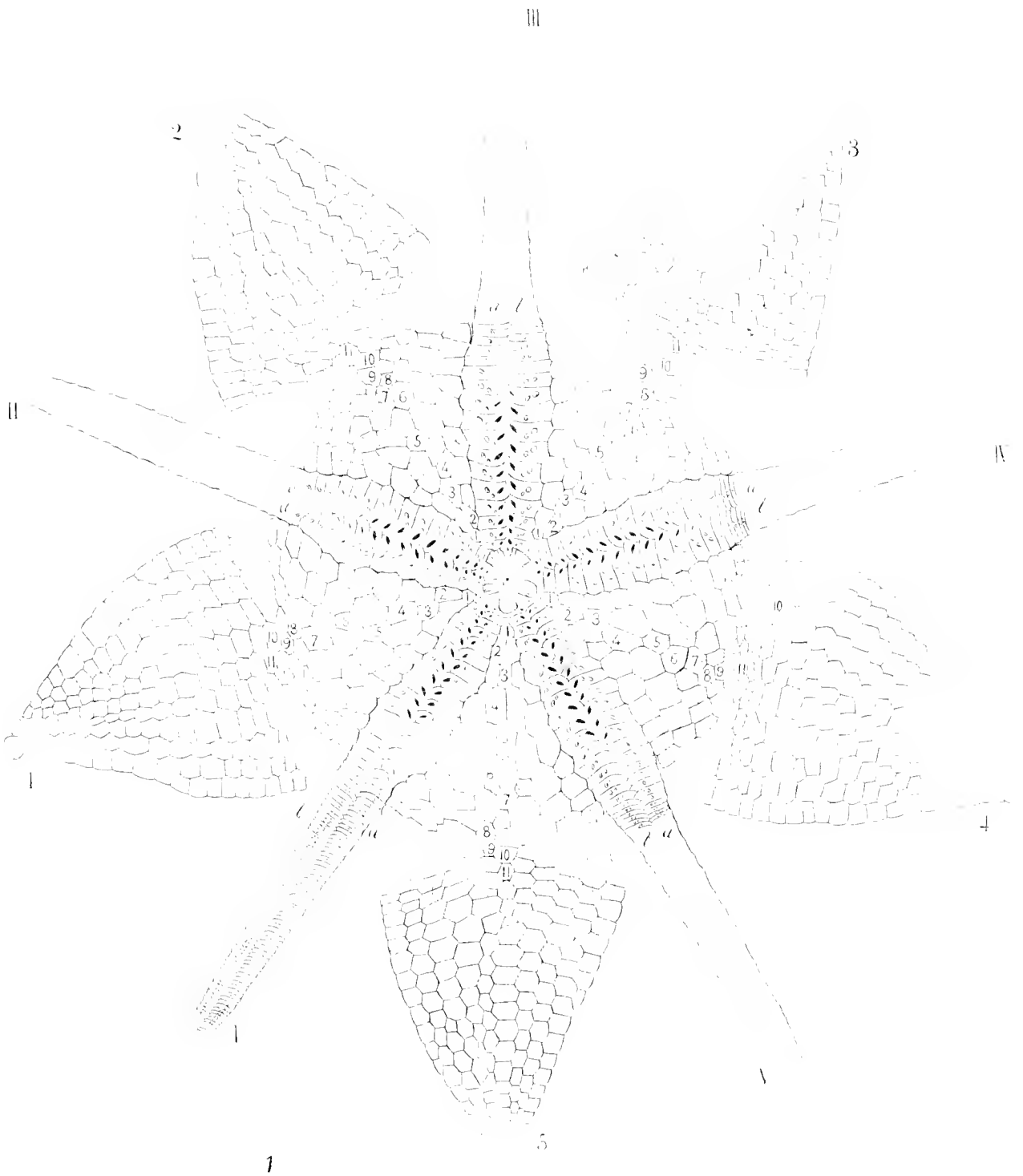
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PLATE 27.

Pholidechinus brauni sp. nov. Page 299.

Figs. 1–6. Keokuk Group, Lower Carboniferous, Crawfordsville, Indiana.

Fig. 1. Mus. Comp. Zoöl. Coll., 3,109, (from R. T. J. Coll.) holotype. Natural size. Ambulacra narrow throughout. Nine columns of plates in both interambulacral areas at the mid-zone, but a tenth column exists dorsally in area C. Tubercles and some spines are clear in both ambulacral and interambulacral areas of this specimen. Drawings, Plate 28, figs. 2, 9.

Fig. 2. F. Braun Coll., paratype. Natural size. Nine columns of plates in interambulacra A and 1. Teeth in place, and ambulacral plates only on the peristome. Drawing, Plate 28, fig. 1.

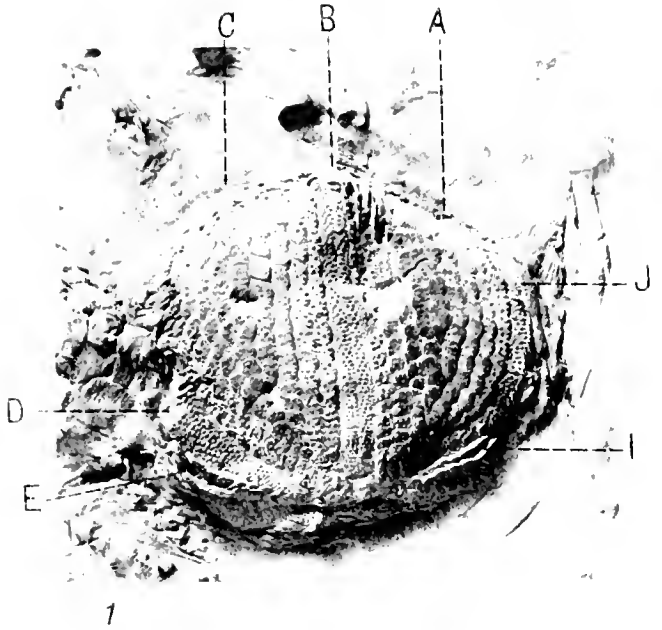
Fig. 3. British Mus. Coll., E 10,678 (from R. T. J. Coll.), paratype. Natural size. A tenth column originates in interambulacrum A earlier than in fig. 1. Drawings, Plate 28, figs. 4–6.

Fig. 4. Yale Mus. Coll., 321, paratype. × 3. This figure with figs. 5, 6, represents the most perfect lantern known in a Palaeozoic echinoid. Teeth in place. Peristome in part in place on the lantern, consisting of low, wide imbricate ambulacral plates only. The pyramids are wide-angled, producing as a consequence a wide and flaring lantern which is largely visible from this ventral view. There are wide outwardly curving spaces for long interpyramidal muscles (compare Plate 2, figs. 19, 20); the outer ends of the epiphyses, braces, and in area D a compass are visible in this view.

Fig. 5. Same specimen, dorsal view. × 3. Five teeth nearly or quite in place and in line with the pyramidal sutures. In areas B, J, H, and F, narrow epiphyses and braces are in place. In area D, a compass also exists, though slightly displaced; distally it is not bifurcate, probably due to wear.

Fig. 6. Same specimen, profile view. × 3. The lantern is inclined at an angle of about 45°, foramina magna moderately deep. Teeth visible ventrally and just above the foramina dorsally, narrow epiphyses are in place, capping the half-pyramids; braces are in place between the epiphyses, and the compass is just visible in area D. In area F, a wide space exists between the pyramids for a long interpyramidal muscle. (Compare Plate 2, fig. 19, and text-fig. 207, p. 184.)

Photographs by F. A. Saunderson; drawings of the lantern by J. Henry Blake.



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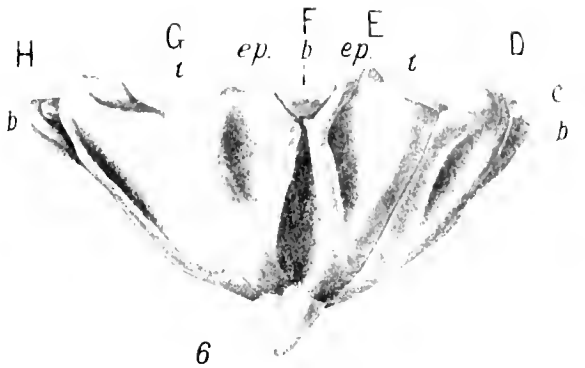

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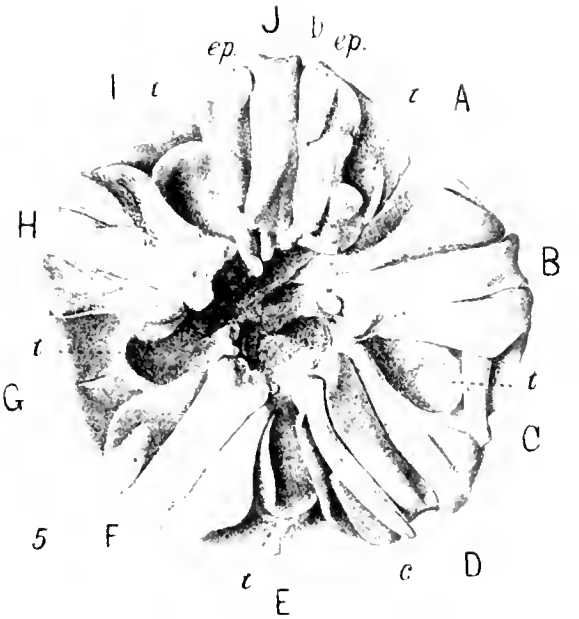

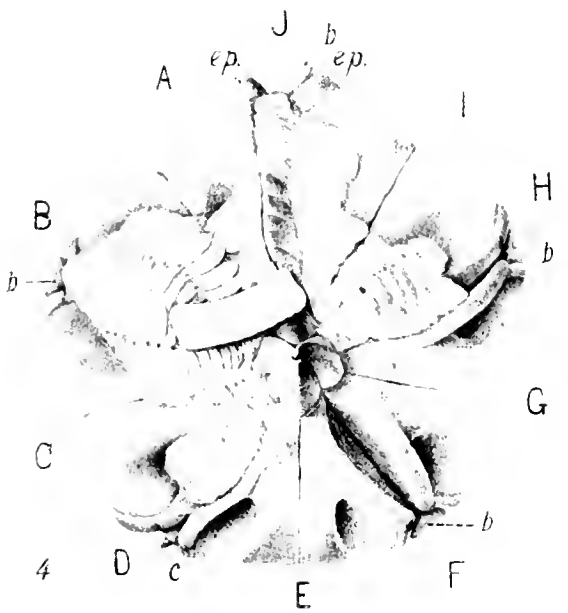

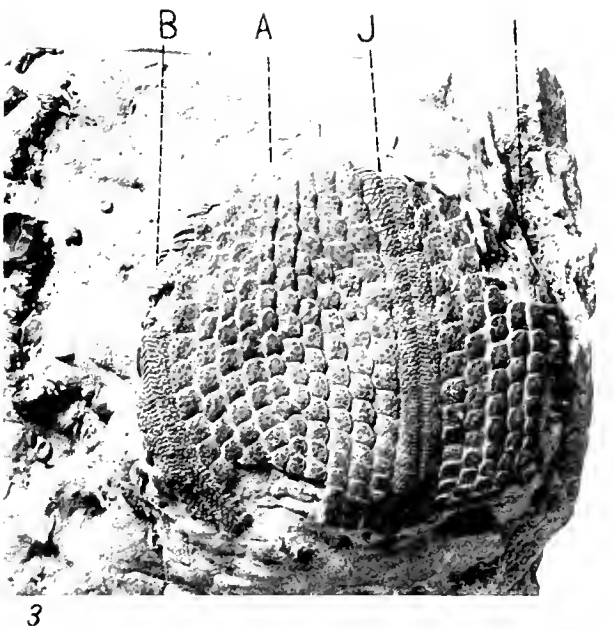

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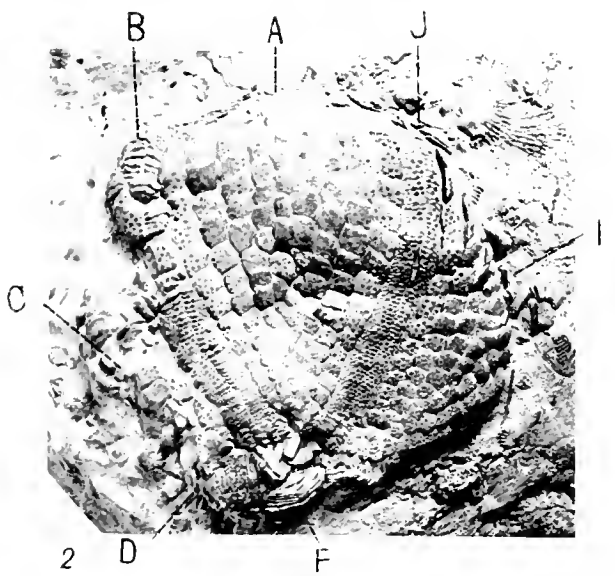

HENRY BLAKE DEL. F. A. SAUNDERSON PHOTO.

HELIOTYPE CO. BOSTON.

PLATE 28.

Pholidechinus brauni sp. nov. Page 299.

Figs. 1–9. Keokuk Group, Lower Carboniferous, Crawfordsville, Montgomery County, Indiana.

Fig. 1. F. Braun Coll. Paratype. × 2.1. Ambulacra narrow throughout, plates laterally meeting the interambulacra or alternate plates in part nearly or quite cut off from interambulacral contact. Pore-pairs slightly biserial. Interambulacra with nine columns in each area. The primordial interambulacral plate is in the basicoronal row in area I, and is restored in area A. Interambulacral plates imbricating strongly dorsally and laterally and rounded upward and toward the ambulacrum on either side, except the median column, which is rounded and imbricates laterally in two directions (compare text-fig. 32, p. 75). Teeth in place, ambulacral plates only on the peristome. Same specimen as photograph, Plate 27, fig. 2.

Fig. 2. Mus. Comp. Zool. Coll., 3,109 (from R. T. J. Coll.), holotype. × 2.1. Ambulacral plates ventrally are all primaries, meeting the interambulacrum equally. Ten columns of plates in interambulacrum C, the last column originating late. The beveled edges of the plates show clearly below the initial plate of column 8. There are flanges on the outer and dorsal border of each plate, compare fig. 9. Spines and tubercles in place. Same specimen as photograph, Plate 27, fig. 1.

Fig. 3. Same specimen as fig. 2, showing the details of tubercles and spines from the area marked X, in fig. 2. × 8.

Fig. 4. British Mus. Coll., E 10,678 (from R. T. J. Coll.), paratype. × 2.1. Ten columns of plates in interambulacrum A and apparently in I, the tenth column originating earlier than in fig. 2. Column 9 in both areas imbricates dorsally and laterally in two directions; columns 7 and 8 in area A drop out passing dorsally. Same specimen as photograph, Plate 27, fig. 3.

Fig. 5. Same specimen as fig. 4, from the area marked X in that figure, showing alternate plates nearly or quite cut off from the interambulacrum. Pore-pairs in peripodia. × 5.4.

Fig. 6. Same specimen as fig. 4, from the area marked XX in that figure, showing alternate plates narrowed but not cut off from the interambulacrum. × 5.4.

Fig. 7. Amer. Mus. Nat. Hist. Coll., $\frac{7-24}{1}$, paratype. × 2.5. In profile to show the lateral beveling; adradial plates are shaded.

Fig. 8. The same specimen. × 2.5. Shows ambulacral plates alternately meeting and cut off from interambulacral contact; biserial pore-pairs and beveling of plates.

Fig. 9. Same specimen as photograph, Plate 27, fig. 1, and this Plate, fig. 2. Holotype. × 3.2. Plates from near the mid-zone of area A, showing delicate attenuated flanges that exist superficially on the dorsal and both sides of column 9, and on the dorsal and lateral border of the plates of other interambulacral columns, a unique specific character as far as known.

Fig. 10. Keokuk Group, Montgomery County, Indiana. Mus. Comp. Zool. Coll., 3,111 (from R. T. J. Coll.), paratype. · 2.2. Dorsal portion of a test showing two low, wide genitals each with numerous genital pores.

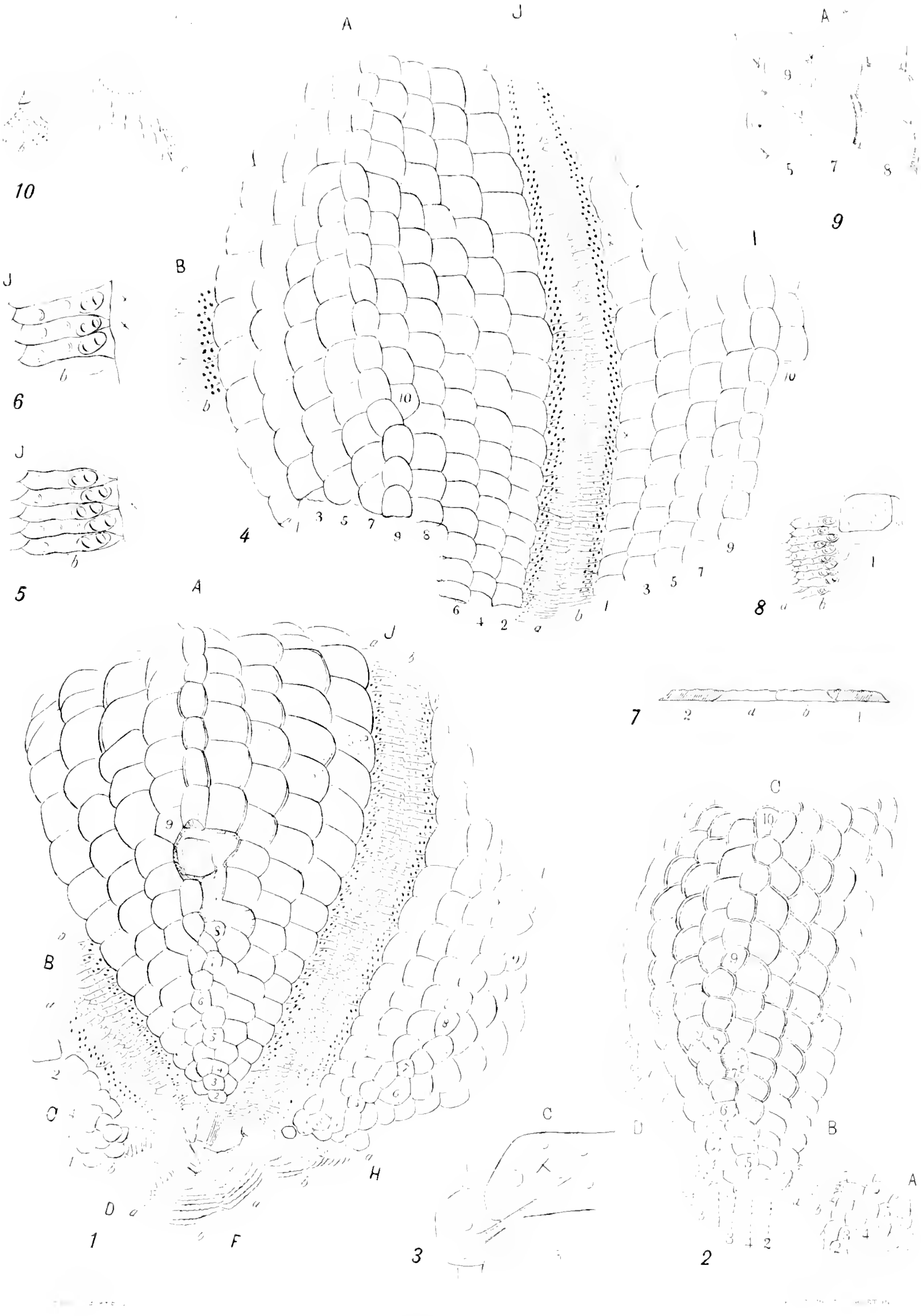
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PLATE 29.

Palaeechinus quadriserialis Wright. Page 305.

Fig. 1. Lower Carboniferous Limestone, Rathkeale, County Limerick, Ireland. British Mus. Coll., E 193. Natural size. Test elliptical, ambulacra narrow, four columns of plates in each interambulacral area. Apical disc small. Drawings, Plate 30, figs. 1–4.

Palaeechinus ellipticus M'Coy. Page 307.

Fig. 2. Lower Carboniferous, Millicent, Clare, County Kildare, Ireland. Holotype. Natural size. Griffith Collection, Science and Arts Mus. Coll., Dublin. Test elliptical, ambulacra narrow, five columns of plates in each interambulacral area. Drawings, Plate 30, figs. 8–10.

Palaeechinus elegans M'Coy. Page 308.

Fig. 3. Lower Carboniferous, Hook Head, Fethard, County Wexford, Ireland. Holotype. Natural size. Griffith Collection, Science and Arts Mus. Coll., Dublin. Test spheroidal, ambulacra narrow, five columns of plates in each interambulacral area, apical disc and periproct well preserved. Apical disc small, being proportionately about 16 % of the diameter of the test. Drawings, Plate 31, figs. 1–4.

Fig. 4. Another specimen of this species on the same slab.

Perischodomus biserialis M'Coy. Page 401.

Fig. 5. On same slab as figs. 3, 4. Cotype. Natural size. Dorsal view; one of M'Coy's two original specimens of this species. Interambulacral plates rounded and imbricating dorsally and from the center of each area laterally and over the ambulacra (pp. 402, 403).

Palaeechinus elegans M'Coy. Page 308.

Fig. 6. Same specimen as fig. 3, apical region enlarged. × 4. Oculars imperforate, adorally covering the ambulacra and laterally the interambulacra in part on either side. Though the oculars are imperforate, Baily in his figure of this specimen shows two pores in each ocular plate (pp. 309, 363). Genitals with 3 to 5 pores each, genitals E and G have three pores each, genital C has apparently four pores, and genital A has five pores; a number of periproctal plates are in place. Drawing, Plate 31, fig. 4.

Palaeechinus (?) **minor** sp. nov. Page 310.

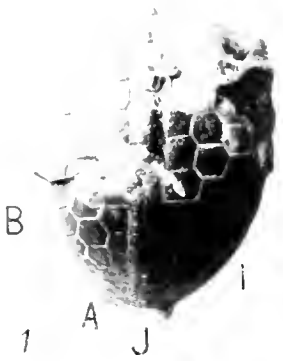
Fig. 7. Kinderhook Group, Lower Carboniferous, Burlington, Iowa. Chicago Univ. Coll., 9,054, holotype. Natural size. Internal sandstone mold. Ambulacra narrow, six columns of plates in an interambulacral area. Drawing, Plate 31, fig. 6.

Fig. 8. Upper Burlington Limestone, Lower Carboniferous, Burlington, Iowa. Mus. Comp. Zool. Coll., 3,051, paratype. Natural size. Internal sandstone mold. Six columns of plates in four interambulacral areas, but in one interambulacral area there are only five columns of plates. Impressions of all oculars and genitals in place. Oculars all insert. Apical disc measures 8 mm. in diameter.

Palaechinus (?) **konigii** M'Coy. Page 450.

Fig. 9. Arenaceous shale, Lower Carboniferous, Rahan's Bay, Dunkineely, County Donegal, Ireland. Griffith Collection, Science and Arts Museum, Dublin. Holotype. Natural size. Interambulacral plates only. Drawings, Plate 31, fig. 7.

Fig. 1 photographed at the British Museum; figs. 2, 9, by A. C. Bridle in Dublin; figs. 3–7 by F. A. Saunderson; fig. 8, by H. W. Tupper.



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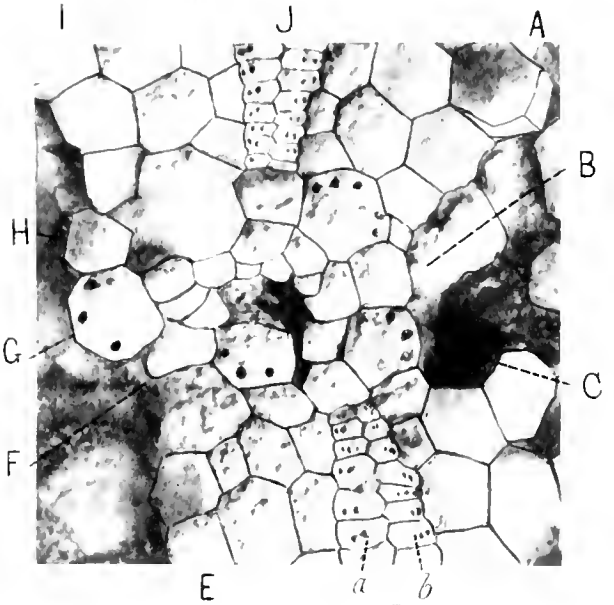

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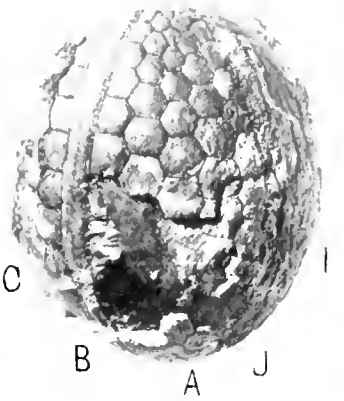

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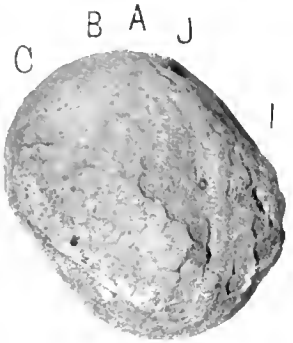

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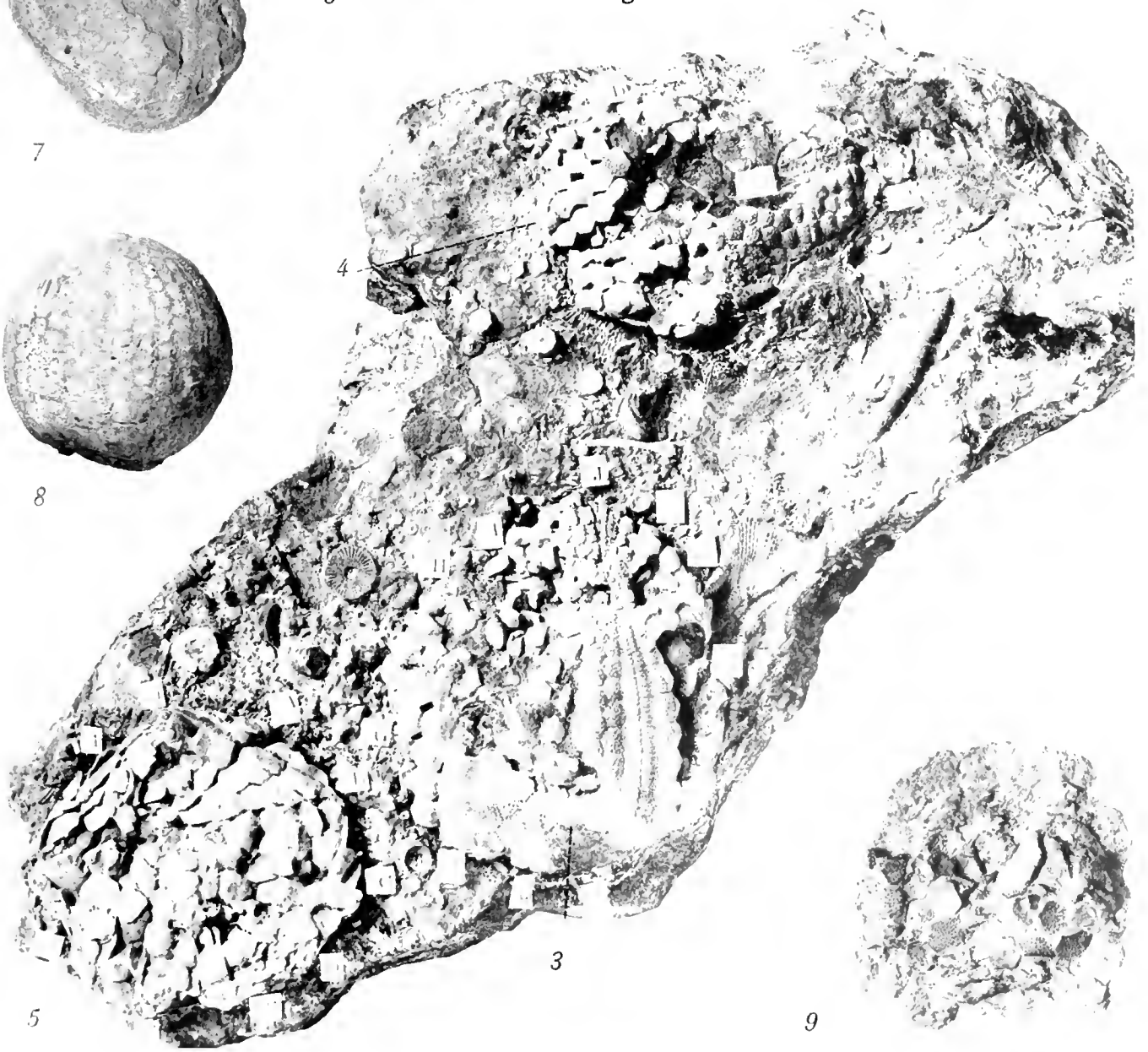

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PLATE 30.

Palaeechinus quadriserialis Wright. Page 305.

Fig. 1. Same specimen as photograph, Plate 29, fig. 1. × 1.5. Test elliptical, with four columns of plates in each interambulacral area. In the upper part of the figure the plates are present as indicated by spine tubercles; the lower part is represented by an internal mold of the bases of the plates.

Fig. 2. Same specimen, from the area marked X in fig. 1, showing ambulacral detail × 4.3.

Fig. 3. Same specimen spread out by the Lovén method. × 1.5. In the aboral part of the specimen, the plates are present as shown by pores in ambulacral plates and tubercles on interambulacral plates. Parts drawn from the mold of the interior are shown in simple outline; restored portions are indicated by dotted lines (compare Plate 29, fig. 1). Ambulacra narrow, plates all primaries, pore-pairs uniserial. In the basicoronal row of the interambulacra there are two plates in each area, in the second row three plates, and in the third row four plates, excepting in area C, in which the fourth column originates in the fourth row, a rare variation (p. 68). Above this zone no more columns are added. (Compare text-fig. 217, p. 191.)

Fig. 4. Same specimen, apical disc, restored as indicated by dotted lines. Enlarged × about 3. Oculars are imperforate, and adorally cover the ambulacra and laterally the interambulacra in part on either side. Genitals with three pores each, and secondary tubercles as on plates of the corona.

Figs. 5–7. Lower Carboniferous, Middleton, County Cork, Ireland (after Wright, 1865, Plate 3, figs. 1a-1c). Holotype.

Fig. 5. Four columns of plates in each interambulacral area. × 0.9.

Fig. 6. The same. Ambulacral detail enlarged.

Fig. 7. The same. A single interambulacral area. × 0.9.

Palaeechinus ellipticus M'Coy. Page 307.

Fig. 8. Same specimen as photograph, Plate 29, fig. 2, holotype. Enlarged ventral border of interambulacrum A to show development; two plates in the basicoronal row, three plates in the second, and four in the third row, the fifth column coming in two rows above the fourth.

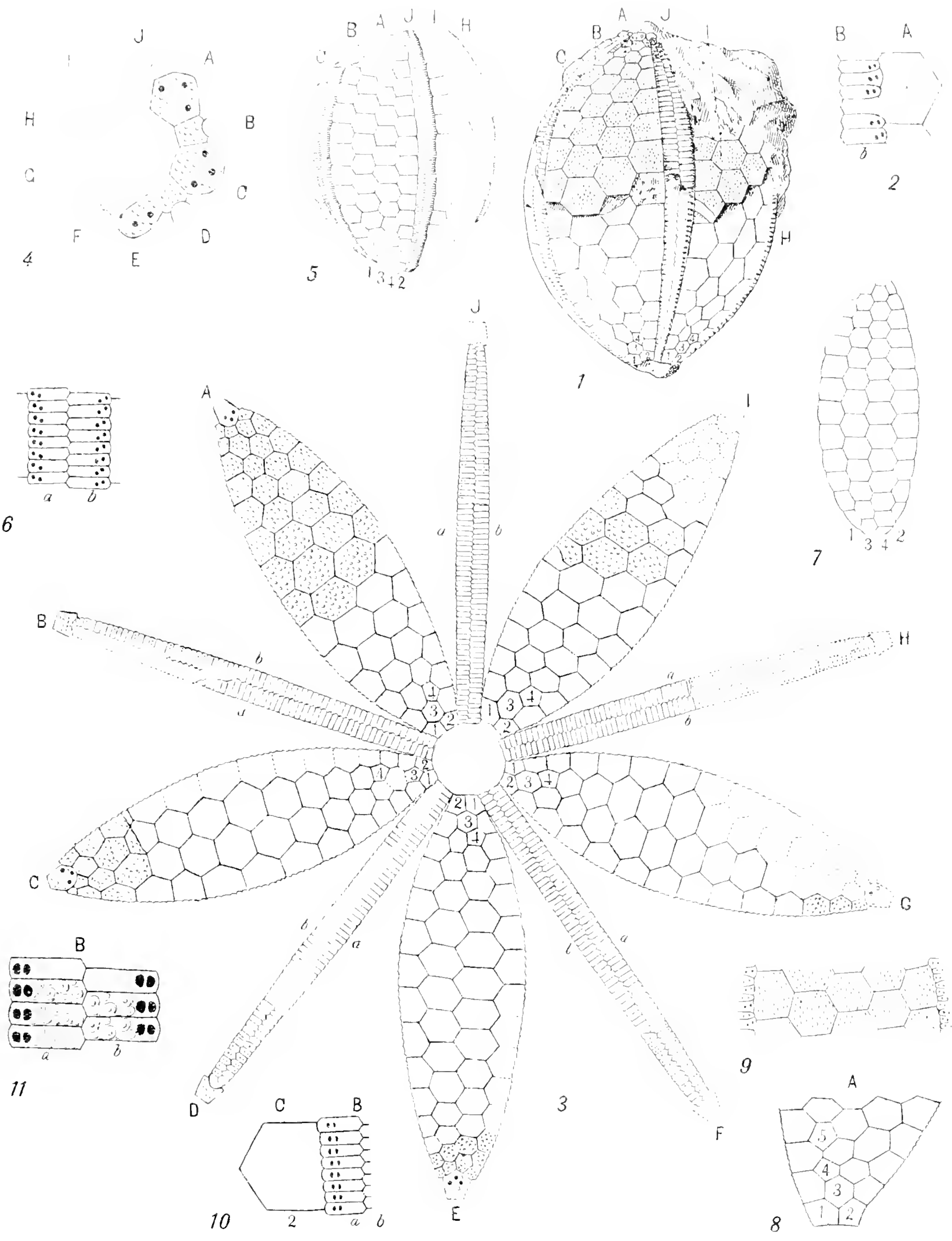
Fig. 9. Same specimen, enlarged × about 1.5. Interambulacrum at the mid-zone with five columns of plates.

Fig. 10. Same specimen. × 3. Ambulacral detail at the mid-zone, showing two columns of primary plates, pore-pairs uniserial (see p. 308).

Palaeechinus elegans M'Coy. Page 308.

Fig. 11. Lower Carboniferous, Hook Point, County Wexford, Ireland. Museum of Practical Geology Coll., London, 6,580. × 6. Ambulacral detail. Same specimen as Plate 31, fig. 5.

Figs. 1 and 11 drawn by G. C. Chubb; figs. 3 and 4 by A. T. Hollick, the other figures are copies of Wright's figures or of my sketches by J. Henry Blake.



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JACKSON ON ECHINI

PLATE 31.

Palaeechinus elegans M'Coy. Page 308.

Fig. 1. Same specimen as photograph, Plate 29, fig. 3. Holotype. × 1.8. Ambulacra narrow, plates all primaries, pore-pairs uniserial. Five columns of plates in an interambulacral area. (Compare text-figs. 9, p. 54; 15, p. 59; 237, p. 231.)

Fig. 2. Same specimen. × 5.4. Ambulacral detail from the area marked X in fig. 1. Ambulacral plates all primaries, pore pairs uniserial.

Fig. 3. Same specimen, showing ambulacral plates beveling over the adradials. × 1.8.

Fig. 4. Same specimen, dorsal area. × 3.5. In area E, column 5 drops out dorsally; oculars shaded, all are imperforate, reaching the periproct and adorally covering the ambulacra and laterally the interambulacra in part on either side. Four genitals nearly or quite in place with three, four, or five pores each; by oversight only three pores are shown in genital A, whereas there should be five pores as seen in the enlarged photographic figure (Plate 29, fig. 6); genital I is wanting. Plates of the periproct are thick and angular.

Fig. 5. Lower Carboniferous, Hook Point, Wexford, Ireland. Museum of Practical Geology Coll., London, 6,580. × 2.7. Five columns of plates in interambulacrum A and spines in place. For an enlarged ambulacrum of the same specimen, see Plate 30, fig. 11.

Palaeechinus (?) **minor** sp. nov. Page 310.

Fig. 6. Same specimen as photograph, Plate 29, fig. 7. Holotype. × 2.7. Internal mold. Ambulacra narrow; all plates (at least in this internal view) primaries with pore-pairs uniserial. The lower part of the figure drawn from area I, is restored ventrally as indicated by dotted lines, and shows the introduction of columns 4, 5, and 6. The upper part of the figure is drawn from area E. The sixth and third columns drop out dorsally. The apical disc is small, oculars are all insert, genitals each with three pores.

Palaechinus (?) **konigii** M'Coy Page 450.

Fig. 7. Same specimen as photograph Plate 29, fig. 9 (after M'Coy, 1844, Plate 24, figs. 1a, 1b). Holotype. × 0.9 and enlarged. Interambulacral plate, such being all that is known of the species.

Fig. 5 drawn by G. C. Chubb; figs. 1–4 from my sketches; fig. 6 from nature; and fig. 7 from M'Coy by J. Henry Blake.

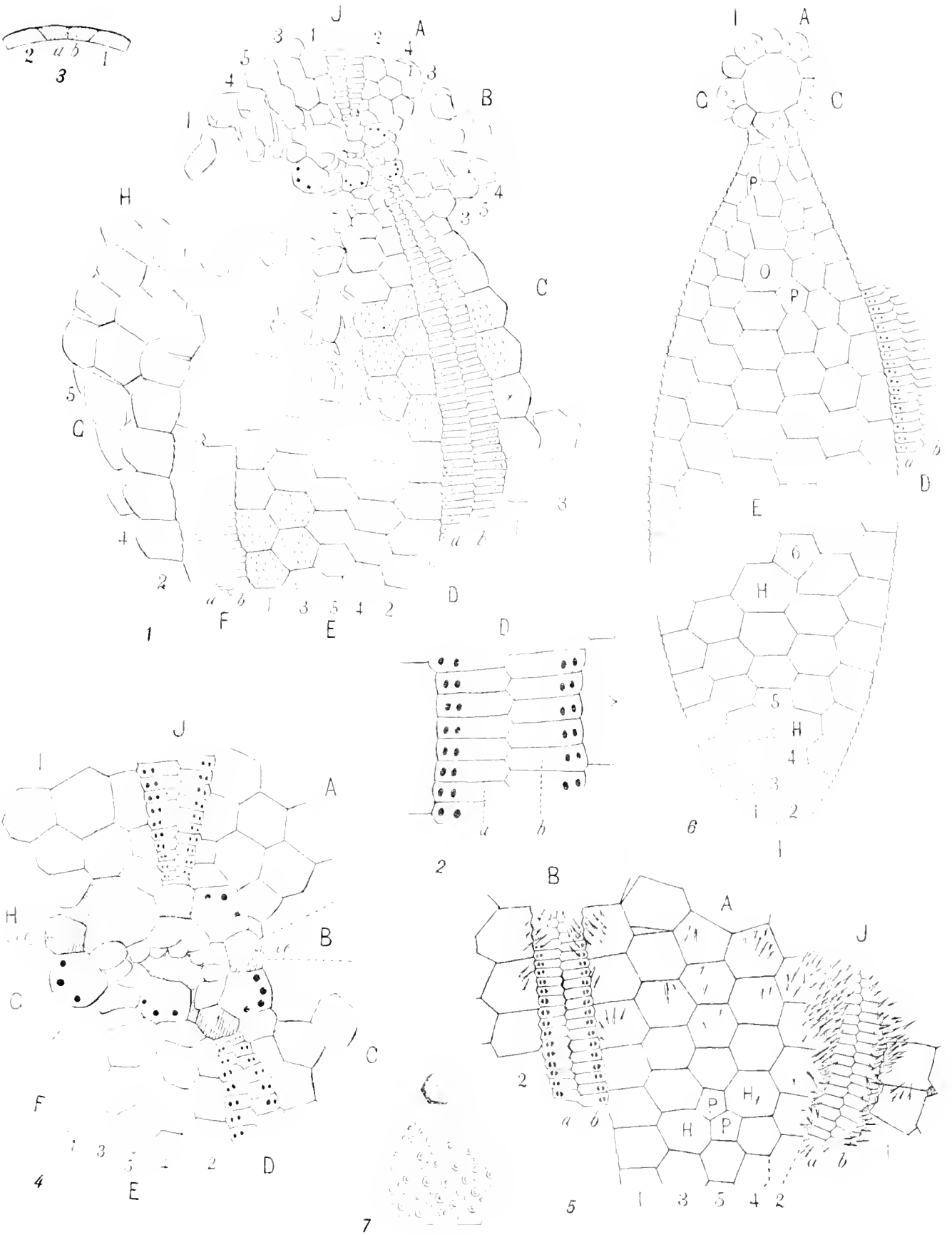
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PLATE 32.

Maccoya burlingtonensis (Meek and Worthen). Page 312.

Figs. 1–3. Upper Burlington Limestone, Lower Carboniferous, Burlington, Iowa.

Fig. 1. F. Springer Coll., 8,003. Natural size. Ventral view. Ambulacral plates ventrally are all primaries, pore-pairs uniserial. At the mid-zone plates are alternately primaries and occluded, pore-pairs biserial. Interambulacrum in the basicoronal row with two plates, in the second row three plates, and in the third row four plates. Drawing, Plate 33, fig. 1.

Fig. 2. E. Kirk Coll. Natural size. Median and dorsal area. Ambulacral plates at the mid-zone are alternately primaries and occluded; pore-pairs biserial, dorsally in the placogenous zone; the ambulacral plates are all primaries and pore-pairs are uniserial. Four columns of plates in interambulacral area A. Tubercles alike on all plates, ambulacral and interambulacral. Drawing, Plate 33, fig. 2.

Fig. 3. F. Springer Coll., 8,002. Natural size. Dorsal half of test. Four columns of plates in each interambulacrum.

Maccoya sphaerica (M'Coy). Page 317.

Fig. 4. Lower Carboniferous, Waterford, County Wexford, Ireland. British Mus. Coll., E 361. Natural size. Ambulacra narrow, pore-pairs biserial at the mid-zone. Five columns of plates in each interambulacral area. Ocelars all insert, periproct exceptionally perfect (p. 319). Drawings, Plate 34, figs. 4–6.

Fig. 5. Lower Carboniferous, probably County Kildare, Ireland. Trinity College Coll., Dublin. Holotype. Natural size. Ambulacra narrow, six or seven columns of plates in each of the several interambulacral areas (p. 318). Drawing, Plate 34, fig. 7.

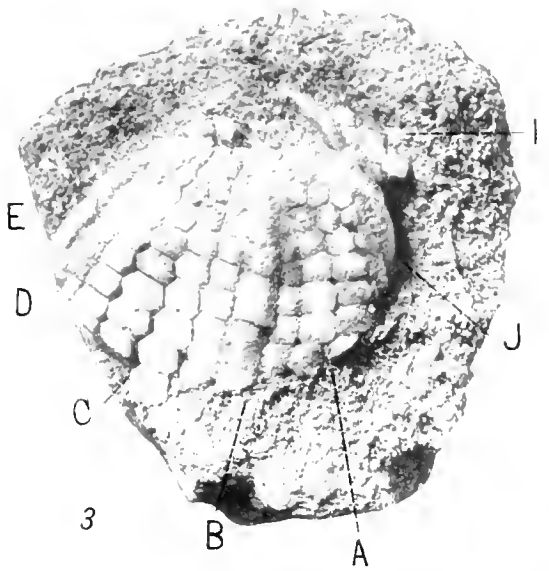
Pholidechinus brauni sp. nov. Page 299.

Fig. 6. Keokuk Group, Lower Carboniferous, Crawfordsville, Indiana. F. Springer Coll., 8,019, paratype. Natural size. An internal mold, with nine columns of plates in interambulacral area A, the median column is very narrow. (Compare similar view of Koninckocidaris, Plate 20, fig. 5.)

Palaeechinus (?) **minor** sp. nov. Page 310.

Fig. 7. Base of Burlington Limestone, Lower Carboniferous, Burlington, Iowa. E. Kirk Coll. Paratype. Natural size. Six columns of plates in each of the five interambulacral areas.

Figs. 1–3, 6, 7 from photographs by F. A. Saunderson; fig. 4 taken in the British Museum; fig. 5 taken in Dublin by A. C. Bridle.



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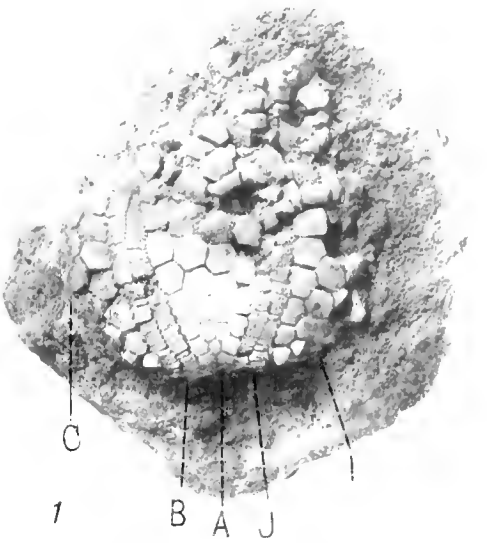

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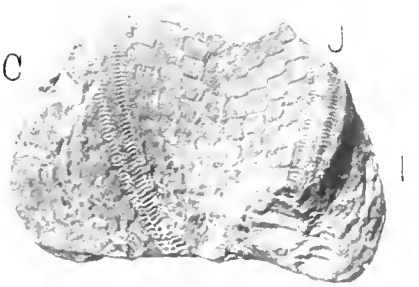

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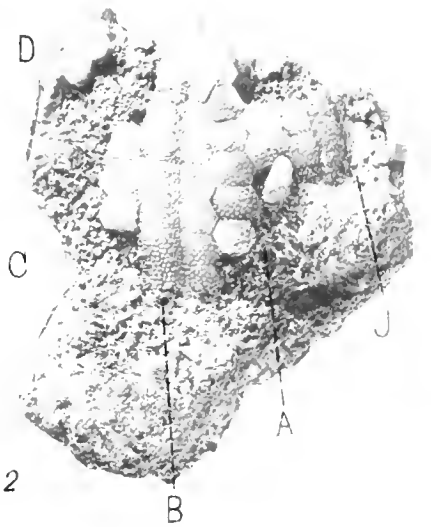

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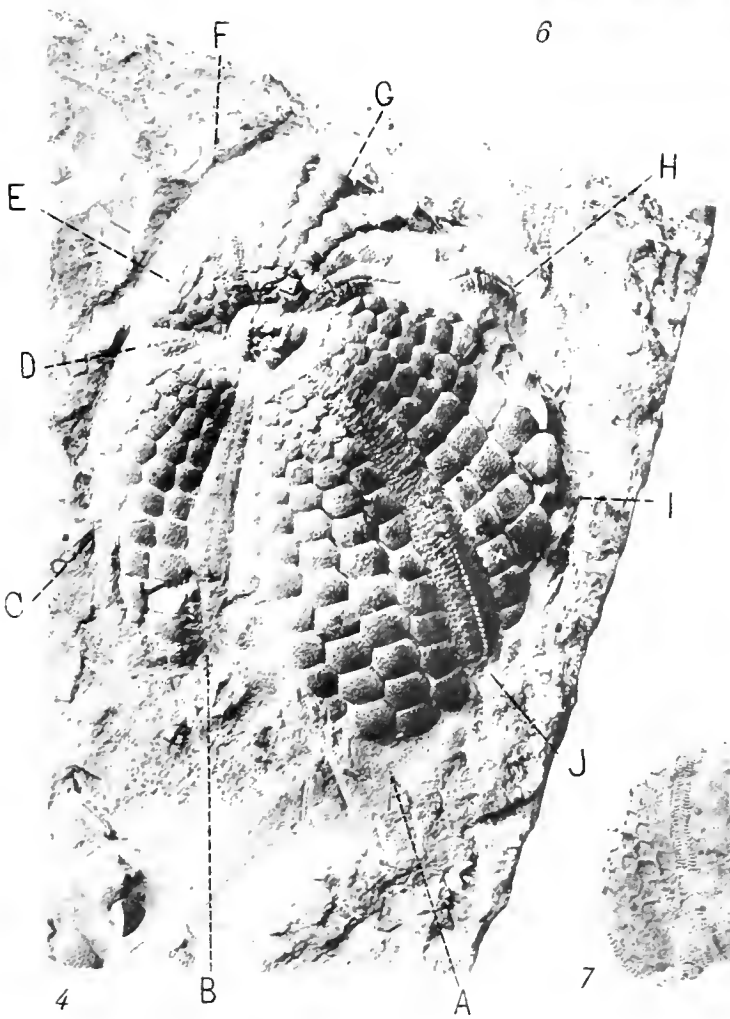

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PLATE 33.

Maccoya burlingtonensis (Meek and Worthen). Page 312.

Figs. 1–5. Upper Burlington Limestone, Lower Carboniferous, Burlington, Iowa.

Fig. 1. Same specimen as photograph, Plate 32, fig. 1. × 2.6. Ventral view. Ambulacral plates ventrally are all primaries, with pore-pairs uniserial; at the mid-zone ambulacral plates are alternately primaries and nearly or quite occluded, with pore-pairs biserial (p. 55). Interambulacrum with two plates in the basicoronal row, three plates in the second row, and four plates in the third row. (Compare text-figs. 16, p. 59; 237, p. 231.)

Fig. 2. Same specimen as photograph, Plate 32, fig. 2. × 2.7. Ambulacral plates at the mid-zone, alternating primaries and occluded, with pore-pairs biserial; at the dorsal portion representing the placogenous zone, ambulacral plates are all primaries and pore-pairs are uniserial as in the youthful plates ventrally (fig. 1). Four columns of interambulacral plates in area A. (Compare text-figs. 10, p. 54; 237, p. 231.)

Fig. 3. After Meek and Worthen, 1866, Plate 16, fig. 3a. Holotype × 0.9. Four columns of plates in an interambulacral area.

Fig. 4. Mus. Comp. Zool. Coll., 3,049. External view. × 3.5. Ambulacral plates are alternately primaries and occluded, with pore-pairs biserial.

Fig. 5. The same individual plates as fig. 4. Internal view. × 3.5. All ambulacral plates are primaries and pore-pairs are uniserial, also the adambulacral plate is rounded on the adradial suture which it is not on the exterior (p. 60). (Compare figs. 4 and 5 with Plate 34, figs. 2, 3.)

Maccoya intermedia (Keeping). Page 314.

Fig. 6. Lower Carboniferous, Hook Head, County Wexford, Ireland. Palaeontological Museum, Munich. × 1.8. Dorsal portion of a test. Ambulacral plates are alternately primaries and occluded, with pore-pairs biserial. Four columns of interambulacral plates in area A, numerous secondary tubercles.

Fig. 7. Same specimen. × 3.6. Ambulacral detail and tubercles.

Fig. 8. Same specimen. × 3.5. Viewed from the interior. In this view, ambulacral plates all cross the half-areas, pore-pairs are uniserial, and are farther from the interambulacral suture than on the exterior. (Compare Plate 34, figs 2, 3.)

Fig. 9. The same specimen and view as fig. 8. × 6. Ambulacral plates more enlarged.

Fig. 10. Carboniferous, Hook Head, County Wexford, Ireland (after Keeping, 1876, Plate 3, fig. 2). Sedgwick Museum, Cambridge, England. Holotype. × 1.3. For structural details of this specimen see Plate 34, figs. 2, 3.

Fig. 11. Lower Carboniferous, Hook Head, Wexford, Ireland. Sedgwick Museum Coll., Cambridge, England, 6. Enlarged. Four columns of plates in each interambulacral area; ocular F is exsert, all other oculars are insert.

Fig. 12. Same horizon and locality, Sedgwick Museum, Cambridge, England. Enlarged. Genitals are in contact shutting out all the oculars from the periproct, a very unusual character in the Palaeozoic (p. 89). Three or five pores in each genital plate.

Maccoya phillipsiae (Forbes). Page 316.

Figs. 13, 14. Caradoc conglomerate, Silurian [?], under Worcester Beacon, England (after Forbes 1848, Plate 29, figs. 1, 1a. Holotype.

Fig. 13. View of the specimen which is evidently poorly preserved. × 0.9.

Fig. 14. Enlarged and partially restored. Ambulacral plates are alternately primaries and narrow occluded plates. Five (?) columns of plates in an interambulacral area.

Figs. 1, 2, 4, 5 drawn from nature, and 11 12 from my sketches by J. Henry Blake; figs. 3, 10, 13, 14 copied by W. M. Barrows; figs. 6–9 drawn by Anton Birkmaier.

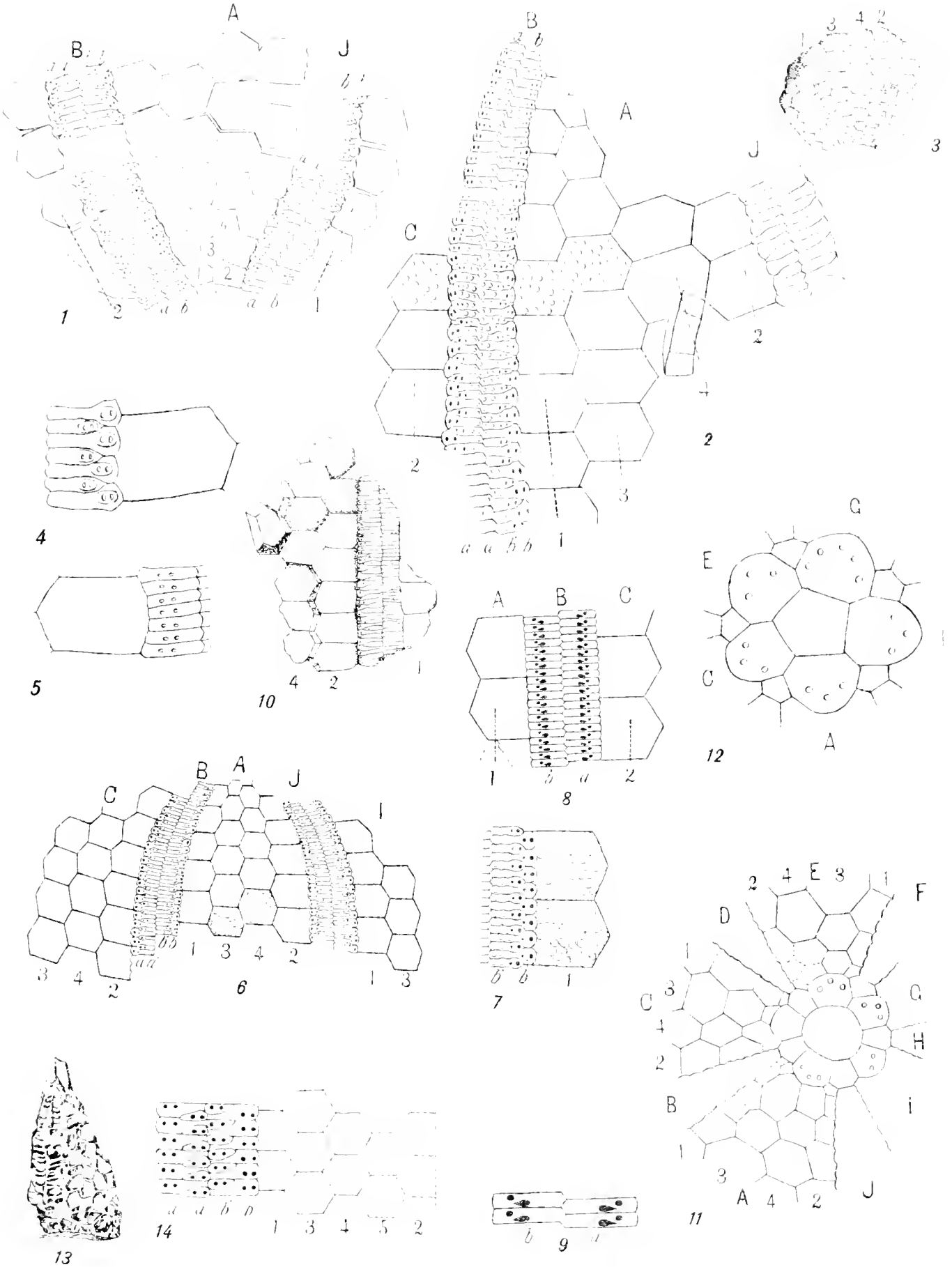
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PLATE 34.

Maccoya intermedia (Keeping). Page 314

Fig. 1. Lower Carboniferous, Hook Head, County Wexford, Ireland. Palaeontological Museum, Munich. × 1.2. Four columns of plates in two interambulacral areas. The only ocular preserved is insert.

Fig. 2. Lower Carboniferous, Hook Head, County Wexford, Ireland. Sedgwick Museum Coll., Cambridge, England. Holotype. × about 4.6. On account of the separation of plates on the adradial suture, the structure is very clear. Ambulacral plates are alternately primaries and occluded, pore-pairs biserial. Interambulacral plates bevel under ambulacrals on the adradial suture, so that here the adradial plates present an inclined face. On the outer border of this face there are impressions of the primary plates only; but on the inner, or proximal border of the inclined face, there are impressions of each ambulacral plate, as on the interior all ambulacral plates cross the half-areas, as shown in fig. 3 (p. 60).

Fig. 3. Same specimen. × about 4. Seen from the interior, all ambulacral plates cross the half-area, and pore-pairs are uniserial, instead of the plates being alternately primary and occluded, with pore-pairs biserial, as occurs on the outer face of the same plates.

Maccoya sphaerica (M'Coy). Page 317.

Fig. 4. Same specimen as photograph, Plate 32, fig. 4. × 1.2. Ambulacral plates are somewhat schematic, and are more correctly given in figs. 5 and 6 (p. 319). Pore-pairs are biserial at the mid-zone, five columns of plates in each interambulacral area. Oculars are all insert, and adorally cover the ambulacra and laterally the interambulacra in part on either side; periproctal plates in place.

Fig. 5. Same specimen. × 2.6. From the mid-zone, alternate ambulacral plates marginally narrowed and nearly excluded from interambulacral contact; pore-pairs biserial (p. 319).

Fig. 6. Same specimen. × 2.4. Dorsal portion enlarged. Ambulacral plates dorsally are all primaries and pore-pairs are uniserial. Oculars all insert and cover the ambulacra and laterally the interambulacra in part on either side; against the oculars young interambulacral plates are existent. Plates of the periproct are thick and angular, the most nearly complete of any periproct known in the family (p. 320). In detail the plates were drawn with great care and are more correct than in fig. 4

Fig. 7. Same specimen as photograph, Plate 32, fig. 5. Holotype. × 3.5. Ambulacral detail from area marked X in the photograph. Ambulacral plates are alternately primaries and occluded, pore-pairs biserial. In the specimen the ambulacral sutures are difficult to see at most parts (p. 317).

Fig. 8. Lower Carboniferous, Whatley, near Frome, Somerset, England. University Museum Coll., Strassburg. Enlarged. Alternate ambulacral plates are narrowed and nearly excluded from interambulacral contact; pore-pairs biserial (p. 320).

Fig. 9. Same specimen, enlarged; plates seen from the interior. All pass directly across the half-area and pore-pairs are uniserial

Fig. 10. Same specimen. × 1.5. From the dorsal area, where plates are all primaries and pore-pairs are uniserial.

Maccoya gracilis (Meek and Worthen). Page 323.

Fig. 11. Upper Burlington Limestone, Lower Carboniferous, Burlington, Iowa. Mus. Comp. Zool. Coll. 3,052, holotype. × 2. Ambulacral plates are alternately primaries, and occluded; seven columns of interambulacral plates in area A; the seventh column is interrupted dorsally by one row of six plates, above which it reappears with a pentagonal plate next to the heptagonal plate, H. Same specimen as photograph, enlarged, Plate 35, fig. 1.

Fig. 12. Same specimen as photographs, Plate 35, figs. 2 and 3 (after Jackson, 1896, Plate 7, fig. 36). External sandstone mold. × 2. Ambulacral detail obscure, restored as indicated by dotted lines in area I, and probably incorrectly (p. 324, compare fig. 11). There are seven columns of plates at the mid-zone as far as shown in each interambulacral area; farther dorsally an eighth column is introduced in each area, and a ninth column, consisting of two or three plates, occurs dorsally in area C.

Fig. 1 drawn by Anton Birkmaier; figs. 2, 3 and 5–10 from my sketches by J. Henry Blake; fig. 4 by G. C. Chubb; fig. 11 from nature by J. Henry Blake; fig. 12 drawn by J. H. Emerton.

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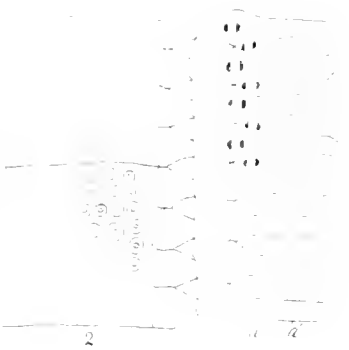

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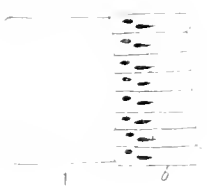

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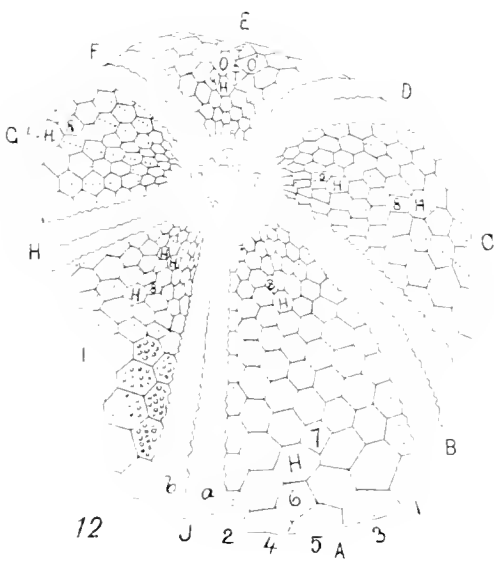

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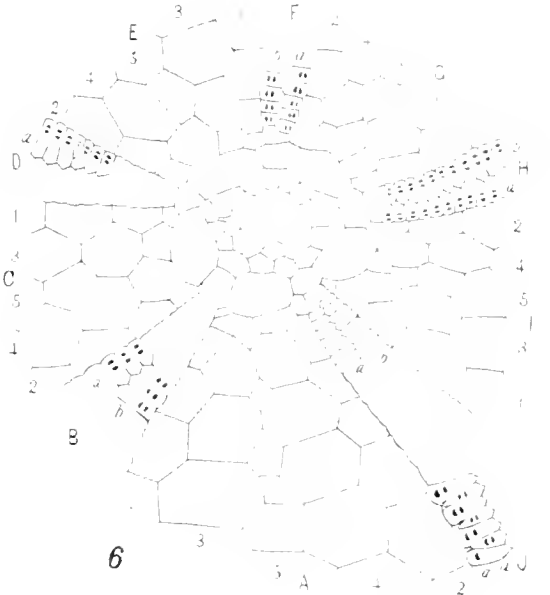

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PLATE 35.

Maccoya gracilis (Meek and Worthen). Page 323.

Fig. 1. Upper Burlington Limestone, Lower Carboniferous, Burlington, Iowa. Mus. Comp. Zool. Coll., 3,052, holotype. × 2. Ambulacral plates alternately primary and occluded; seven columns of interambulacral plates in area A. Drawing, Plate 34, fig. 11.

Fig. 2. Waverly Group, Lower Carboniferous, Menifee County, Kentucky. Mus. Comp. Zool. Coll., 3,062. Natural size. An external sandstone mold. Drawing, Plate 34, fig. 12.

Fig. 3. Same specimen. × 2. Seven columns of interambulacral plates at the mid-zone, eight dorsally in each area and nine columns near the apical disc in area C. Apical disc small. Fig. 2 was lighted from the left and the specimen looks hollow as it is; on the contrary, fig. 3 was lighted from the right and looks in relief, which it is not. The outline of the interambulacral plates and even spine tubercles is very clear for a sandstone mold. As it is an external mold, the orientation is reversed.

Lovenechinus lacazei (Julien). Page 326.

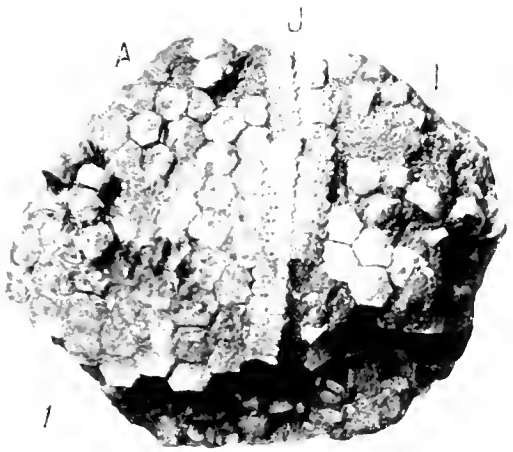
Fig. 4. Lower Carboniferous, Armagh, Ireland. British Mus. Coll., E 10,051. Natural size. Four columns of plates in three interambulacral areas; exsert ocular and genitals in place (p. 328). Drawing, Plate 36, fig. 6.

Fig. 5. Same horizon and locality, British Mus. Coll., E 10,052. Natural size. Shows general spheroidal form and four columns of plates in two interambulacral areas (p. 328). Drawings, Plate 36, figs. 4, 5.

Fig. 6. Lower Carboniferous Limestone, Llysfaen, near Llandulas, Wales. British Mus. Coll., E 3,432. Natural size. Four columns of massive interambulacral plates in area A (p. 329). Drawings, Plate 36, figs. 7, 8.

Fig. 7. Lower Carboniferous Limestone, Kirkby Stephen, Westmoreland, England. Yorkshire Philosophical Soc. Coll. Enlarged × about 1.6. This photograph was taken for me through Dr. F. A. Bather's kindness. Four columns of plates in each ambulacral area and four columns of plates in each interambulacral area, genitals and small exsert ocular in place. This specimen is of much importance as the original described by de Koninck (1869, 1870) as "*Palaechinus sphaericus*," from which species, however, it differs radically in structure, as shown by the drawings and by Dr. Bather's description (pp. 330–334). Drawings, text-figs. 240–243, p. 331.

Fig. 1 from photograph by H. W. Tupper; figs. 2, 3 by F. A. Saunderson; figs. 4–6 taken at the British Museum; fig. 7 by H. Herring at the British Museum.



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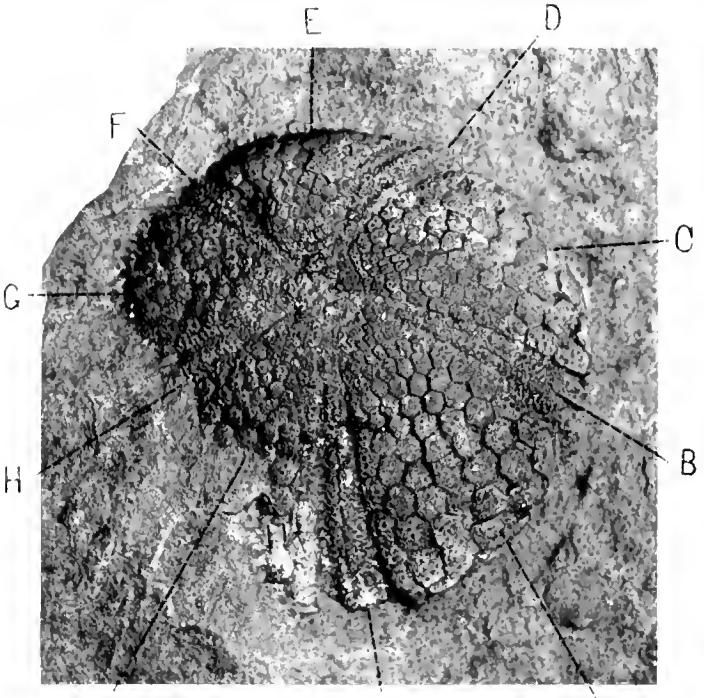

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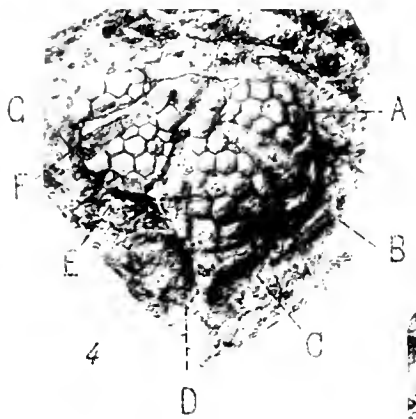

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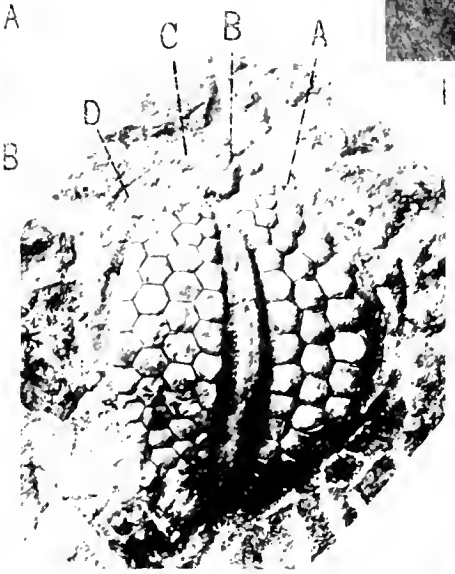

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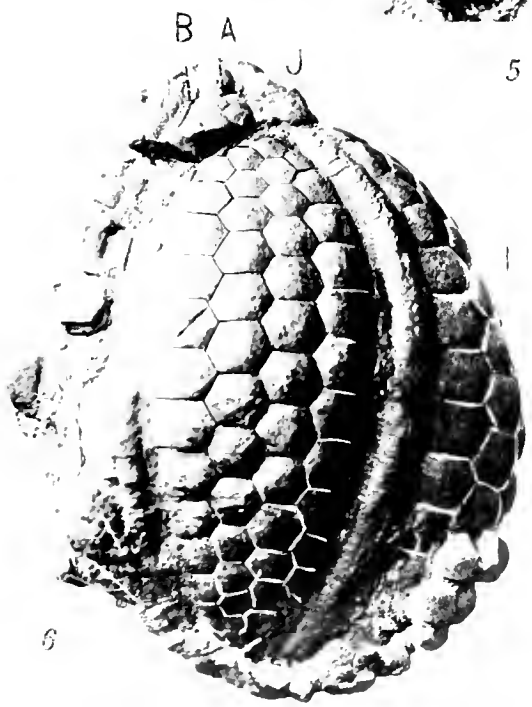

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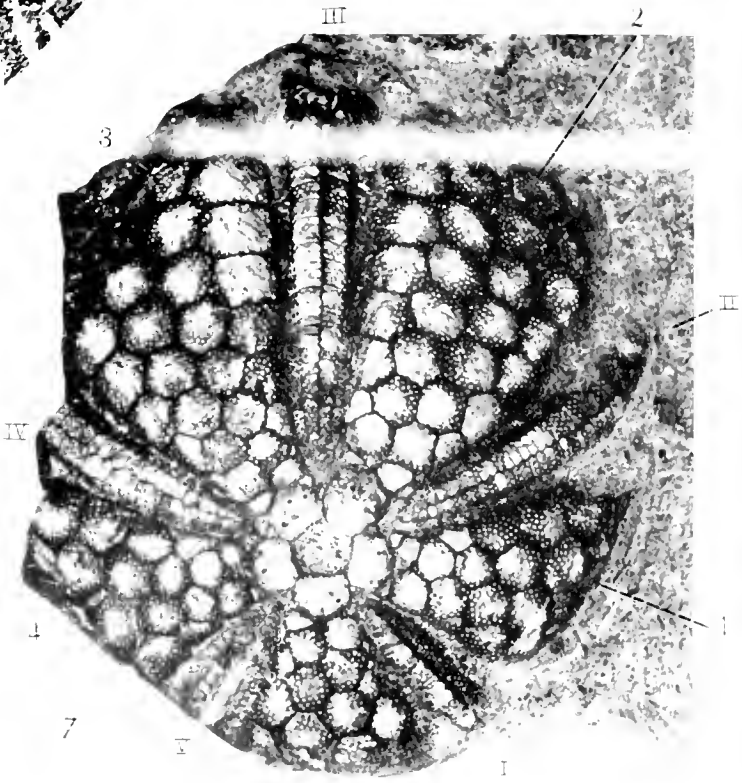

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PLATE 36.

Lovenechinus lacazei (Julien). Page 326.

Fig. 1. Lower Carboniferous, Helsington Barrows, southwest of Kendare. Museum of Practical Geology Coll., London, 16,301. × 1.7. Ambulacral plates at the mid-zone demi- and occluded, pore-pairs biserial; ventrally in area B, all plates are primaries and pore-pairs uniserial for a short distance. In interambulacrum A, plates of columns 1, 2 and 3 are in place, but plates of column 3 partially and column 4 wholly are restored as indicated by dotted lines. In the specimen spaces for these plates exist although the plates are wanting (pp. 328–329). Professor Duncan (1889, p. 200, text-fig. viii) described the ambulacral detail of this specimen as that of "*Palaeechinus ellipticus*," thereby making much confusion. (Compare the type of that species, Plate 29, fig. 2; Plate 30, fig. 10; p. 308.)

Fig. 2. Same specimen, showing primary ambulacral plates ventrally and the passage to demi- and occluded plates higher up, from the area marked X in fig. 1. × 7.

Fig. 3. Same specimen. × 7. Typical ambulacral plates of a half-area at the mid-zone, from the area marked XX in fig. 1

Fig. 4. Same specimen as photograph, Plate 35, fig. 5. × 1.7. Four columns of plates in two interambulacral areas, in area A the four columns are seen only dorsally. The single genital plate preserved has three pores (p. 328).

Fig. 5. Same specimen. × 7. Detail of ambulacrum at the mid-zone, plates are narrow demi- and wide occluded in each half-area.

Fig. 6. Same specimen as photograph, Plate 35, fig. 4. × 1.7. Four columns of plates in three interambulacral areas. Three oculars in place, all of which are exsert (p. 328).

Fig. 7. Same specimen as photograph, Plate 35, fig. 6. × 1.3. Ambulacral plates demi- and occluded, four columns of massive interambulacral plates in area A, a genital with three pores in place (p. 329).

Fig. 8. Same specimen. × 3.5. Ambulacral detail of a half-area from the mid-zone, with wide occluded and narrow demi-plates in a half-area (p. 329).

Figs. 1–3 drawn by A. T. Hollick; all others by G. C. Chubb.

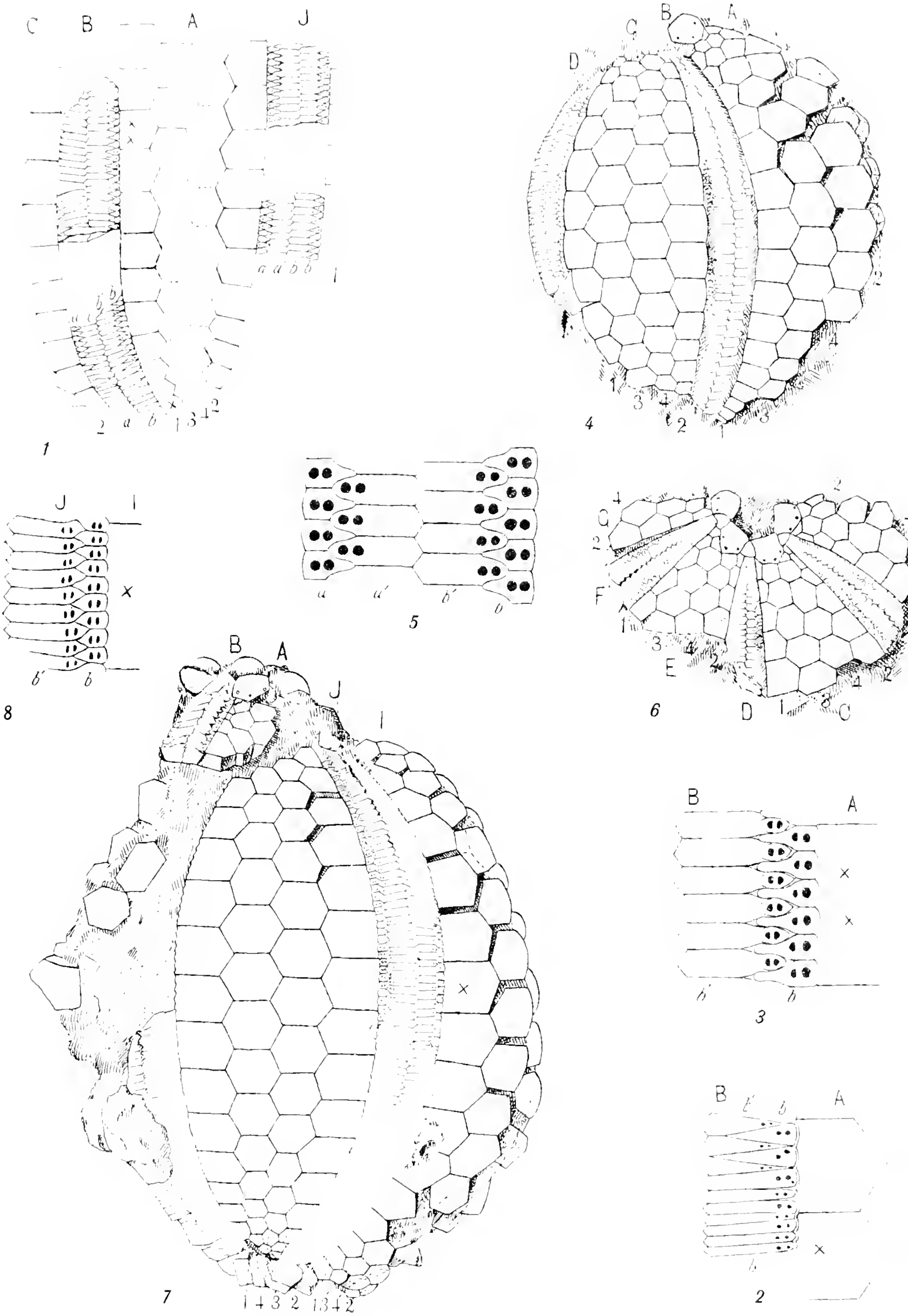
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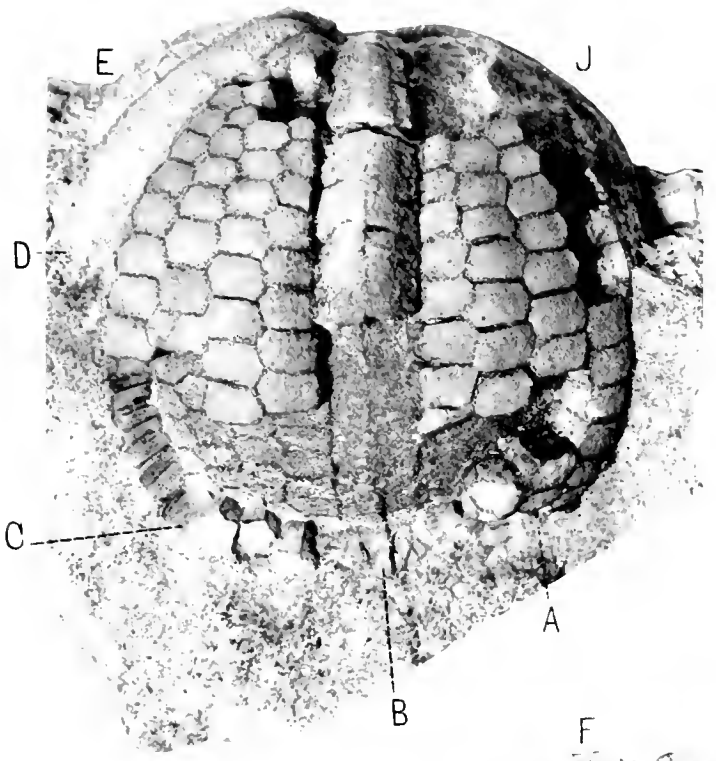
PLATE 37.

Lovenechinus nobilis (Meek and Worthen). Page 335.

Fig. 1 Burlington Group, Lower Carboniferous, Webb City, Missouri. Mus. Comp. Zool. Coll., 3,124 (from R. T. J. Coll.). Natural size. Five columns of thick, massive plates in each interambulacral area. The thickness of the plates is seen well in the lower part of the figure, where also is seen a mold of the internal faces of some plates that are absent. Drawings, Plate 38, figs. 8, 9.

Fig. 2 Same horizon and locality. Mus. Comp. Zool. Coll., 3,123 (from R. T. J. Coll.). Natural size. Fragment of a massive specimen, with one interambulacrum complete at the mid-zone and a more complete ambulacrum. Drawings, Plate 38, figs. 4, 5.

Fig. 3 Burlington Group, Lower Carboniferous, Calhoun County, Illinois. U. S. Nat. Mus. Coll., 33,277. Natural size. This magnificent specimen shows ambulacral detail clearly in area B, and five columns of plates in each interambulacrum. Drawings, Plate 38, figs. 6, 7.



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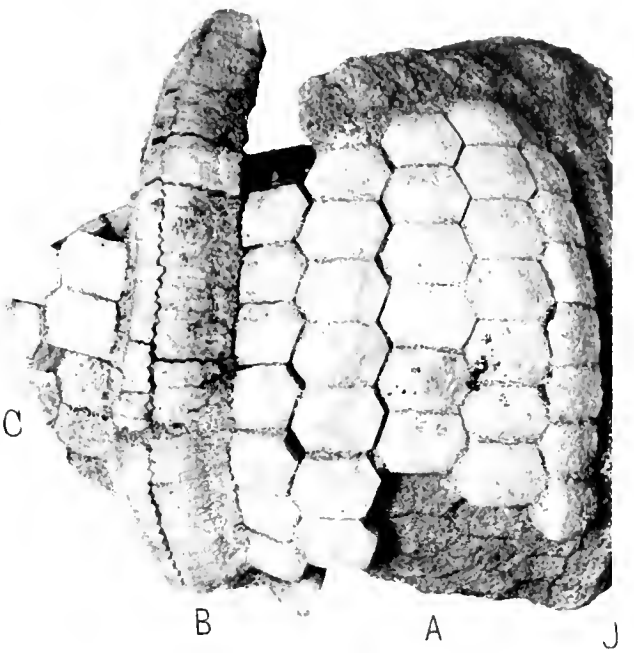

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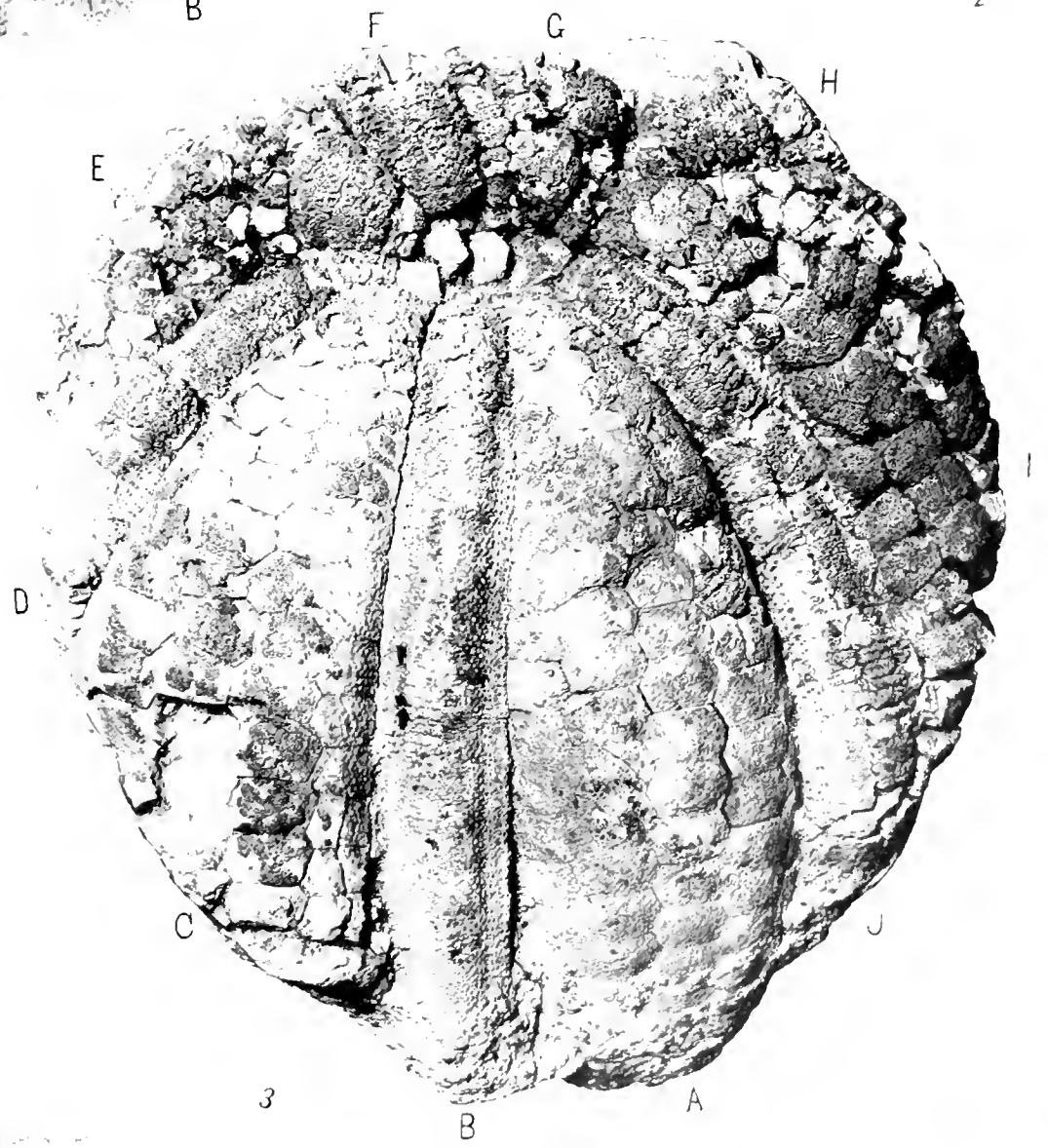

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PLATE 38.

Lovenechinus lacazei (Julien). Page 326.

Figs. 1–3. Lower Carboniferous, Hunsrücken, Prussia (after Tornquist, 1897, Plate 20, figs. 2–4).

Fig. 1. Showing four columns of plates in an interambulacral area (p. 328).

Fig. 2. Enlargement of ventral ambulacral plates of the same, plates are all primaries, pore-pairs in peripodia

Fig. 3. Enlargement of ambulacral plates from the upper end of the corona, plates are occluded and demi-plates in each half-area, pore-pairs biserial.

Lovenechinus nobilis (Meek and Worthen). Page 335.

Fig. 4. Same specimen as photograph, Plate 37, fig. 2. × 0.9. Ambulacral plates are demi- and occluded, five columns of plates in an interambulacral area; tubercles are small secondaries only. The outline of ambulacrum J and the outlines of plates in the lower part of interambulacra A and C are drawn from the mold of their internal faces.

Fig. 5. Same specimen. × 2.7. Ambulacral detail and tubercles of plates from near the mid-zone as indicated by the plate marked X in both figures.

Fig. 6. Same specimen as photograph, Plate 37, fig. 3. × 3.5. Ambulacral detail of a half-area from near the mid-zone. In four plates in this figure the inner tongue of the demi-plates is superficially separated from the outer portion of the plates by the widening and confluence of the outer portion of the occluded plates.

Fig. 7. Same specimen. × 3.5. Ambulacral detail from the same area near the apical disc. In the right half-area there is one demi-plate, but other plates are all primaries and pore-pairs are uniserial.

Fig. 8. Same specimen as photograph, Plate 37, fig. 1 × 0.9. Five columns of interambulacral plates in two areas. The plates are very massive and thick.

Fig. 9. Same specimen. × 0.9 Section, partially schematic, showing the curvature of the areas and ambulacral plates beveling over the interambulacrals on the adradial sutures. Both ambulacral and interambulacral plates are thicker in the middle of their areas than at the adradial sutures. The inner face of the test presents a curve of one arc, thus differing from the exterior of the test where marked radial elevations occur in both ambulacral and interambulacral areas.

Lovenechinus mutatus (Keyes). Page 335.

Figs. 10, 11 Keokuk Limestone, Lower Carboniferous, Keokuk Iowa (after Keyes, 1891, Plate 15, figs. 4a, 4b). Holotype.

Fig. 10. × 0.9. Five columns of plates in an interambulacral area. Ambulacral fields are strongly elevated in melon-like ribs

Fig. 11. Same specimen, ambulacral detail enlarged. Plates occluded and demi- a single row of tubercles only on a plate. The sutural contact of the demi- and occluded plates in each half-area is serrate, as in *L. septies* (Plate 45, fig. 3) not deeply reëntrant and tongue-like, as in *L. nobilis*, fig. 5

Figs. 1–3 copied by W. M Barrows; figs. 4–9 drawn by J. Henry Blake; figs. 10, 11 from Keyes.

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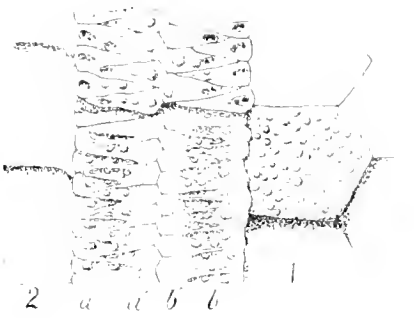

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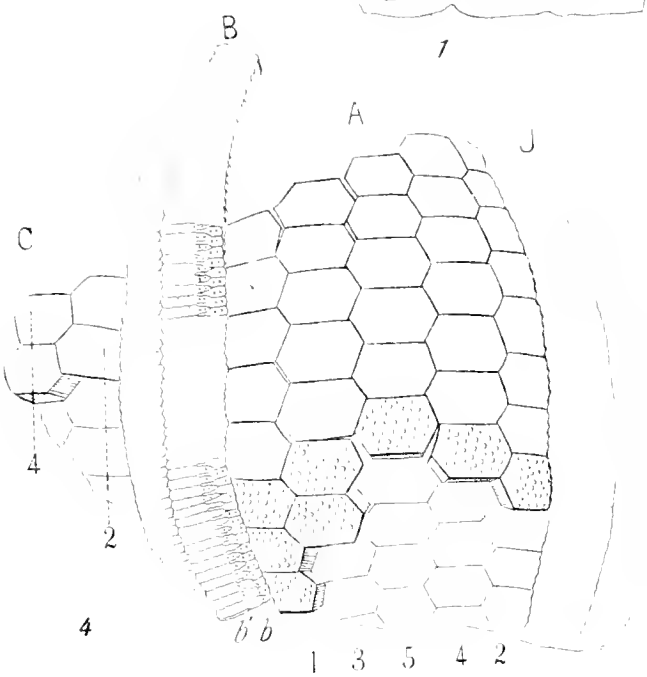

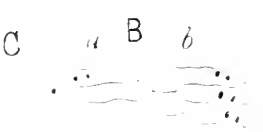

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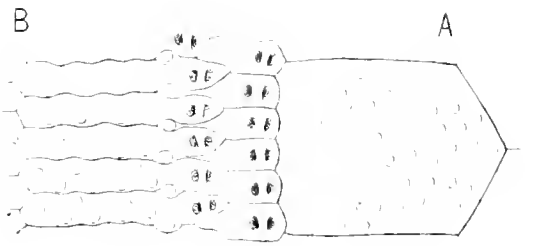

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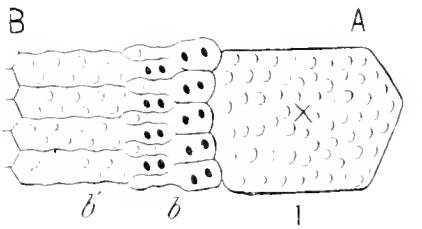

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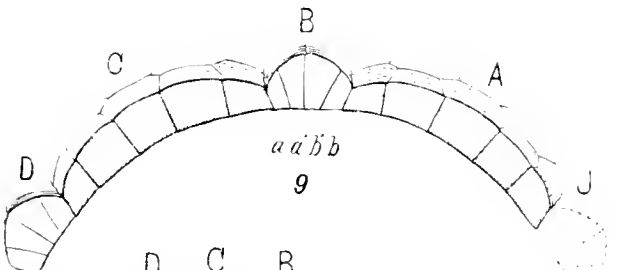

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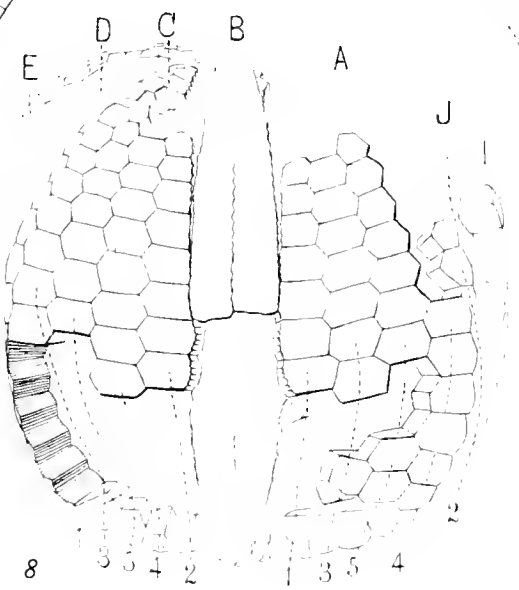

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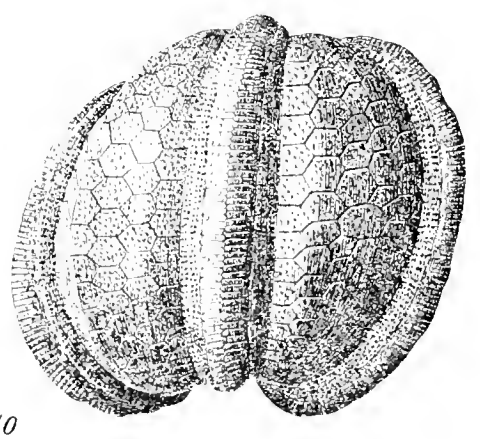

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PLATE 39.

Lovenechinus missouriensis (Jackson). Page 337.

Figs. 1, 2, 4-6. Burlington Group, Lower Carboniferous, Webb City, Missouri. Silicified internal molds with sutures bounding the plates represented by elevated walls and pores by siliceous plugs or tubes.

Fig. 1. Mus. Comp. Zool. Coll., 3,140 (from R. T. J. Coll.). Natural size. Young individual. Initial plate of column 5 in area A is at the mid-zone. The apical disc measures proportionately about 20 % of the diameter of the test. Drawings, Plate 40, figs. 1, 2; Plate 41, fig. 2 (p. 340).

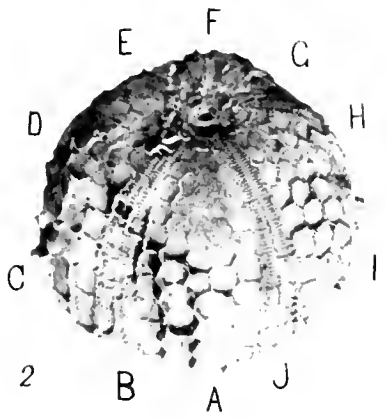
Fig. 2. Same specimen, enlarged. × 1.4

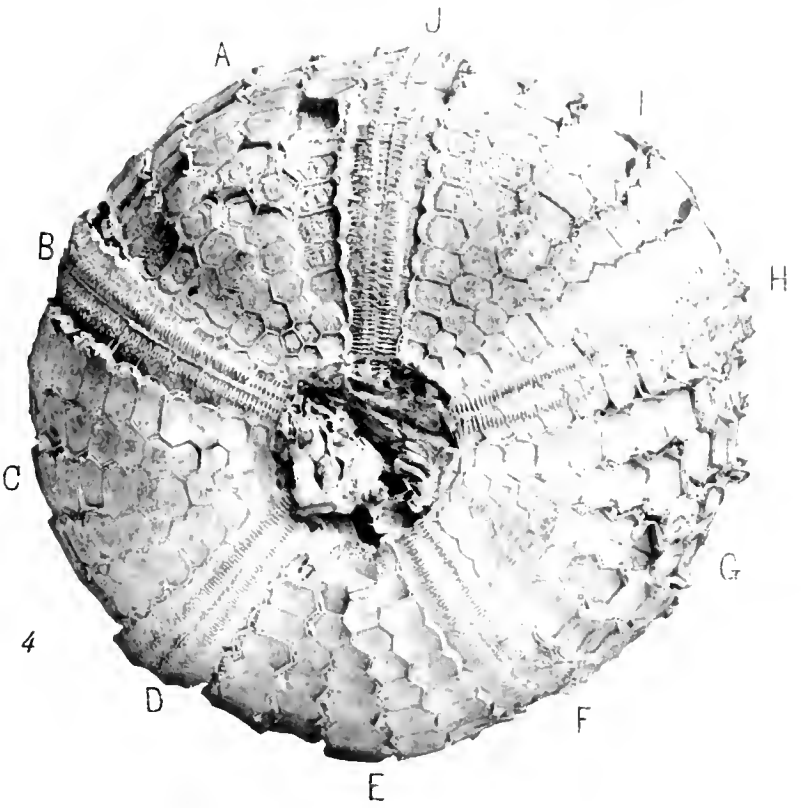
Fig. 3. Burlington Group, Lower Carboniferous, Joplin, Missouri. F. Braun Coll. Natural size. Medium sized specimen. Five columns of plates in all interambulacral areas, ocelars and genitals all in place, the latter with four or five pores each. The apical disc measures proportionately about 21 % of the diameter of the test. Drawing Plate 41, fig. 3 (p. 342).

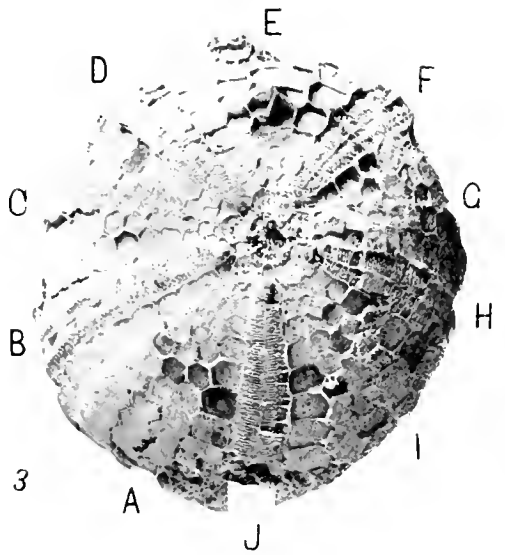
Fig. 4. Mus. Comp. Zool. Coll., 3,128 (from R. T. J. Coll.). Natural size. Old-age individual. Ventral view; ambulacral plates ventrally are all primaries, higher up demi- and occluded; five columns of plates in interambulacral areas A and C; a sixth column is represented by one or two plates in areas E, G, and I. Imperfect molds of jaws orally (p. 342).

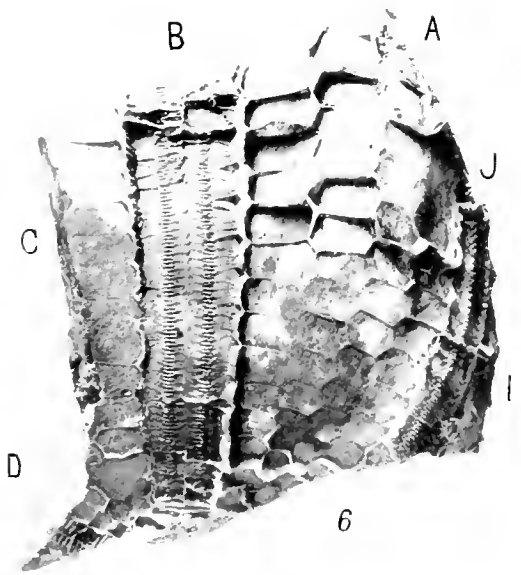
Fig. 5. Same specimen, dorsal view. Natural size. Ambulacral plates at the mid-zone are demi- and occluded, but near the apical disc all plates are primaries. Column 5 drops out dorsally in four interambulacral areas, also columns 1 and 2 in part are incomplete dorsally (compare Plate 42, fig. 6). The apical disc is small measuring proportionately about 16 % of the diameter of the test. Ocelars are all in place and against them the youngest interambulacral plates are in contact. Genitals are all in place, each with three or four pores, which are represented by tubular siliceous casts of the original pores. There are impressions of a few periproctal plates. The bounding margins of each plate are represented by thin siliceous walls as seen best in interambulacra E and G (p. 22). Drawings of figs. 1 and 5: Plate 41, fig. 1; Plate 42, figs. 6, 7 (p. 342).

Fig. 6. Mus. Comp. Zool. Coll., 3,131 (from R. T. J. Coll.). Natural size. Shows ambulacral plates, all primaries ventrally; higher up, occluded and demi-plates. Plates opposite the horizontal sutures of adradial plates are fan-shaped in this internal view. Drawing, Plate 42, fig. 5 (p. 346).









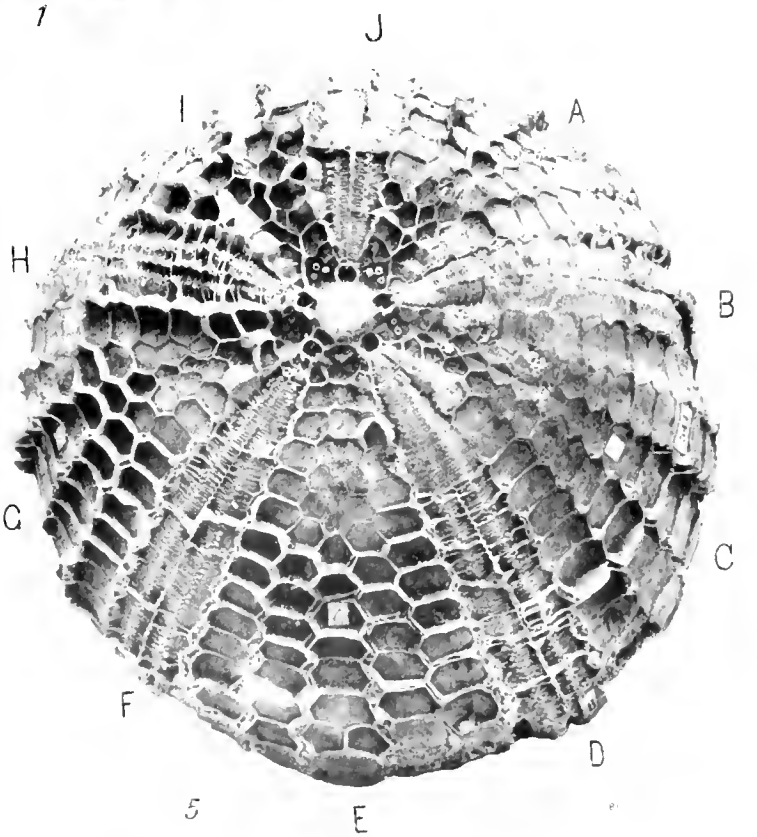


PLATE 40.

Lovenechinus missouriensis (Jackson). Page 337.

Fig. 1. Same specimen as photographs, Plate 39, figs. 1, 2. × 2.5. A young specimen, the youngest of any known Palaeozoic echinoid, restored in part as indicated by dotted lines. There are fewer horizontal rows of interambulacral plates than in the adult, only thirteen or fourteen plates in each of the adradial columns, therefore the point of origin of column 5 is relatively much higher up than in an adult. In area E, column 5 is represented by only one plate, and in area I, a sixth column is represented by a small plate dorsally. The oculars have each a pore and cover the ambulacra and laterally the interambulacra in part on either side as usual (p. 341). For a view of the apical disc of this specimen see Plate 41, fig. 2.

Fig. 2. Same specimen. × 2.6. Drawn from a wax cast of a mold of the exterior, showing the ventral part of area E with the introduction of columns 3 and 4, and tubercles; also ventrally, ambulacral plates, which at this zone are all primaries.

Fig. 3. Burlington Group, Lower Carboniferous, Webb City, Missouri. × 2.7. Mus. Comp. Zool. Coll., 3,078, holotype. Ocular and genital plates enlarged. (Compare text-fig. 244, p. 338.)

Figs. 1 and 2 drawn by J. Henry Blake; fig. 3 by J. H. Emerton.

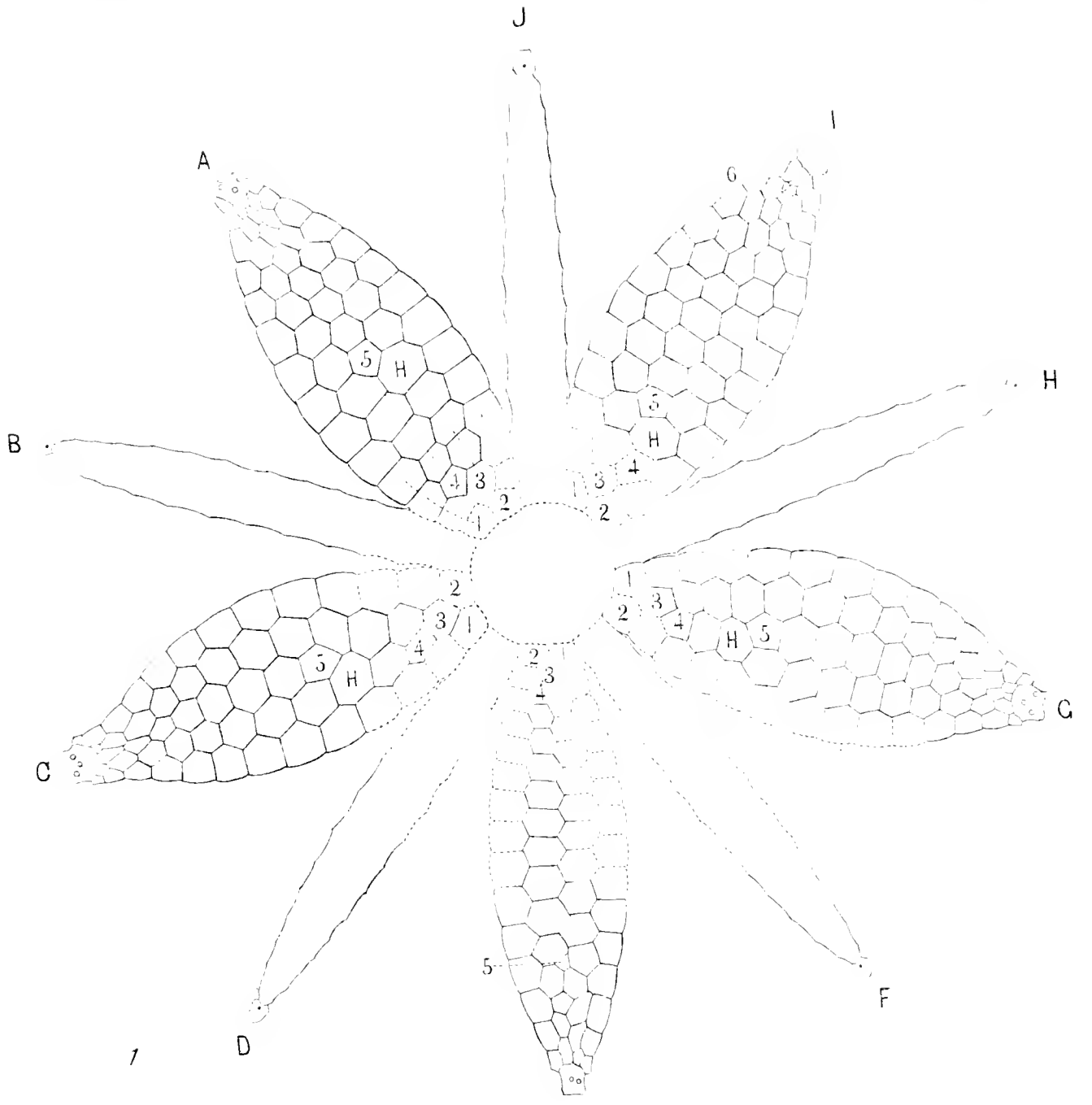

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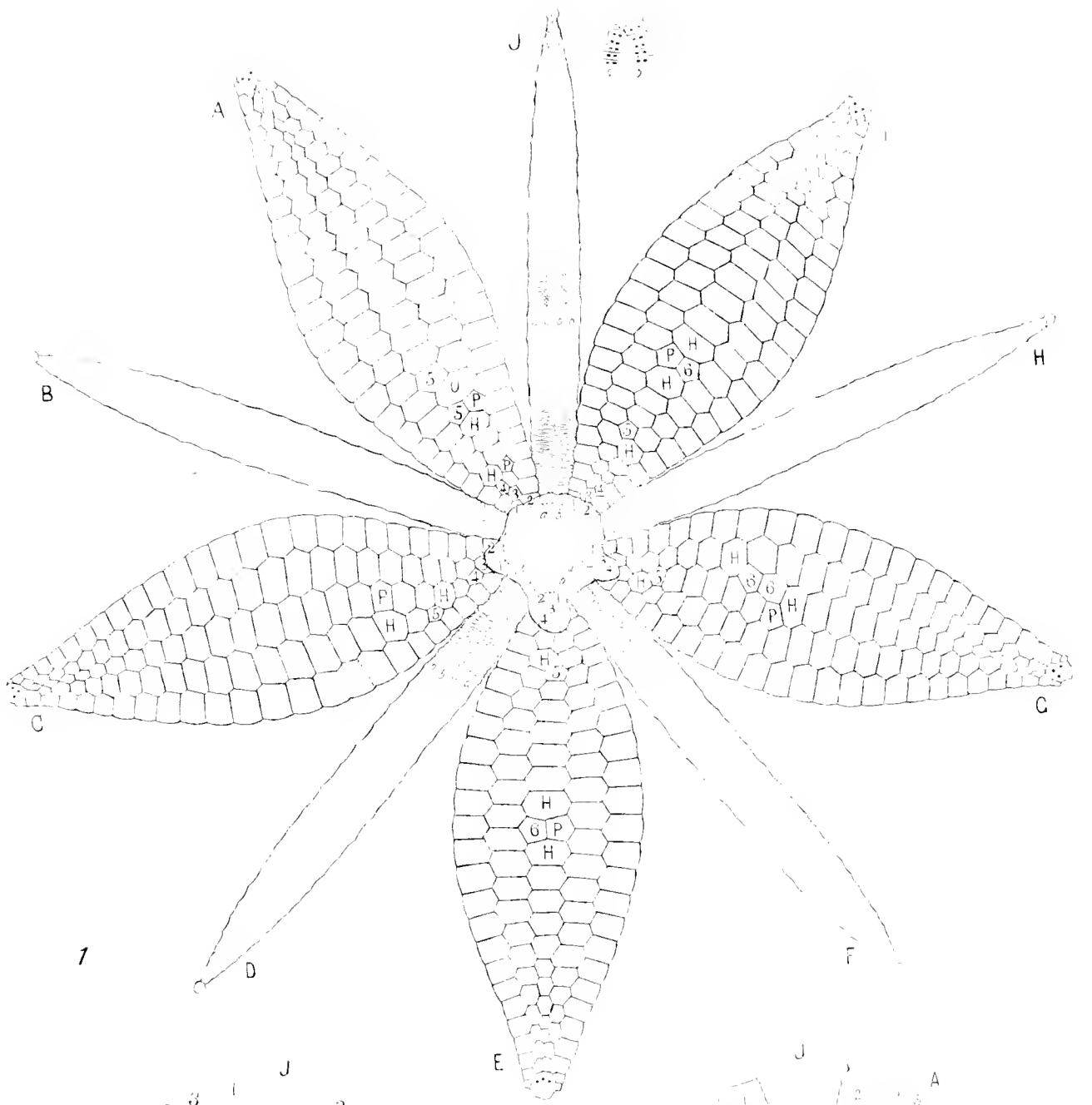
PLATE 41.

Lovenechinus missouriensis (Jackson). Page 337.

Fig. 1. Same specimen as photographs, Plate 39, figs. 4 and 5. × 0.7. In the ambulacra, the plates ventrally are all primaries, at the mid-zone demi- and occluded, near the ocular all primaries. The bases of the interambulacra are in part restored as indicated by dotted lines. In area A, the third plate, P, of column 3 is by exception a pentagon, and its wanting side is compensated for by an adjacent heptagonal plate, H; the initial plate of column 5 is in the eighth row, next it is an exceptional pentagon, P. In the ninth row there are only four plates, but an octagonal plate, O, compensates for the sides wanting in the two adjacent pentagons, 5 and P. In area C, column 5 originates to the left of the center, an exception; a peculiar pentagonal plate, P, in column 4 is compensated for by an adjacent heptagonal plate, H. In area E, a sixth column is represented by a single plate 6, associated with which are a pentagonal plate, P, and two heptagonal plates, H, in column 5. A similar condition exists in area I. In area G, the sixth column is represented by two plates, 6, 6, with an associated pentagonal plate, P, and two heptagonal plates, H. In this specimen there are 26 plates in an adradial column, whereas in the young specimen, Plate 39, fig. 1; Plate 40, fig. 1, there are but 13 or 14 plates in an adradial column. This larger specimen is about three times as large as the smaller specimen yet there are only about twice as many plates in an adradial column. Here as I previously showed (Jackson, 1899, p. 130) in Strongylocentrotus and Arbacia the increase of size in growth of the individual is attained proportionately more by an increase in the size of the plates than it is by the increase in the number of rows of plates (p. 342).

Fig. 2. Same specimen as photograph, Plate 39, figs. 1, 2, also Plate 40, figs. 1, 2. Young individual. × 1.3. Ambulacral plates are all primaries dorsally. Interambulacra abut against the oculars laterally. Oculars D and F are exsert, but all others apparently reach the periproct (p. 89); an ocular pore is in each plate in this internal view, but whether the pores reached the surface is doubtful; probably they did not (p. 89). Genitals A, C, and G have three pores each; the pores of the other genitals are doubtful (p. 341).

Fig. 3. Same specimen as photograph, Plate 39, fig. 3. × 2.1. Column 5 drops out dorsally in areas A to E, but reaches the apical disc in areas G and I. Oculars are all insert; genitals have four or five pores each, an unusually large number for the species (p. 342).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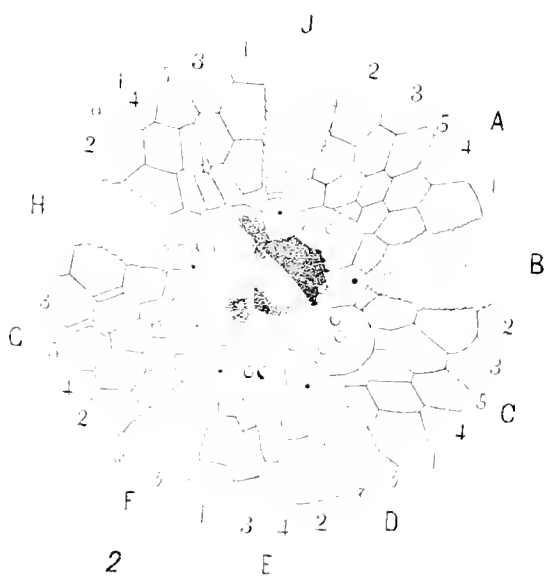
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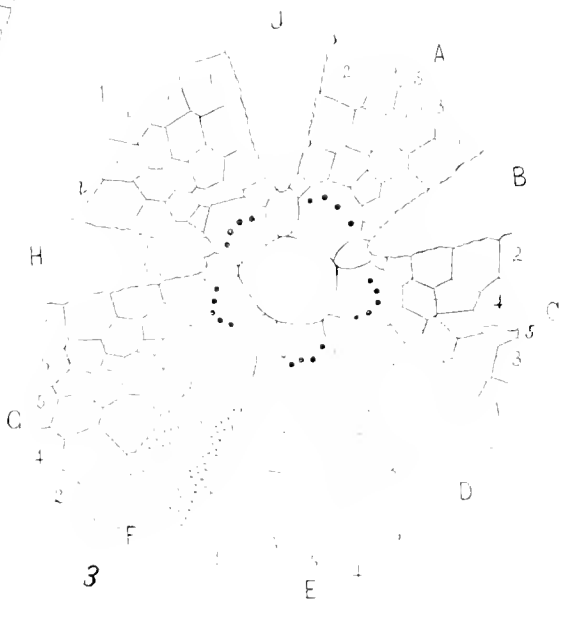
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PLATE 42.

Lovenechinus missouriensis (Jackson). Page 337.

Figs. 1–4. Burlington Group, Lower Carboniferous, Burlington, Iowa. F. Springer Coll., 8,126. An exceptional specimen for surface characters, as most specimens are internal or external silicified molds. Same specimen as photograph, Plate 46, fig. 4 (p. 340).

Fig. 1. A perfect ventral area to show developing stages. × 3.3. Ambulacral plates ventrally are primaries, and pore-pairs are uniserial; a little higher up ambulacral plates are alternately primaries and occluded and pore-pairs are biserial; at the upper part of this figure the plates are demi- and occluded, and pore-pairs biserial, here having attained the full generic character. In the interambulacrum there are two plates in the basicoronal row, three plates in the second row, and four plates in the third row, as usual in this family (p. 340).

Fig. 2. Ambulacrum near the mid-zone in area F. × 3.3. Demi-plates are all narrow, and occluded are wide; pore-pairs lie near the interambulacral suture (p. 340). (Compare text-fig. 18, p. 59.)

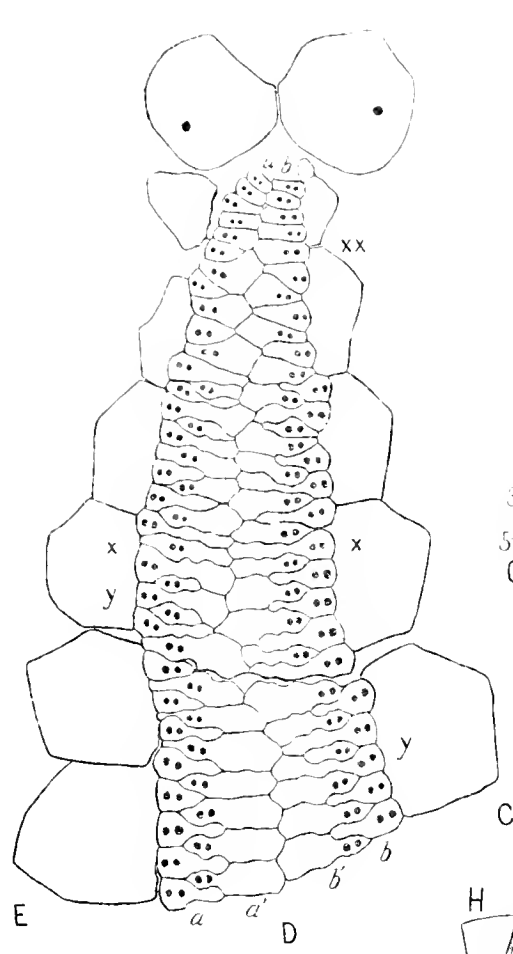
Fig. 3. Dorsal portion of ambulacrum D to show localized stages. × 3.3. In the lower part of the figure, ambulacral plates are demi- and occluded, as is the typical character at the mid-zone. At the zone X, plates are primaries and occluded, with pore-pairs biserial; passing dorsally, with some local irregularities, near the apical disc, at the zone XX, the plates are all primaries and pore-pairs are uniserial, as are the plates built in the youth of the individual, fig. 1. (Compare text-fig. 237, p. 231.) At Y in each half-area occur a few isolated plates. Such have not been observed in any other specimen of the genus, and as a progressive variation, are directly comparable to the typical character of Oligoporus (p. 341). (Compare figs. 1–4 with text-fig. 237, p. 231.)

Fig. 4. Ambulacral plates near the mid-zone enlarged for surface details. × 6.7. A relatively larger tubercle is on the inner tongue-like end of each demi-plate (p. 340).

Fig. 5. Same specimen as photograph, Plate 39, fig. 6. Internal mold. × 2.5. Ambulacral plates ventrally are all primaries; higher up are demi- and occluded; plates opposite the interambulacral sutures are fan-shaped; the pore-pairs are in the middle of the half-areas. Compare fig. 1 for internal and external characters at the same zone, also Plate 43, figs. 1–5 (p. 346).

Fig. 6. Same specimen as photograph, Plate 39, fig. 5, also Plate 41, fig. 1, dorsal area. × 2.5. In interambulacral areas A, E, G, and I, column 5 drops out dorsally. In area I, the plates of columns 1 and 2 are developed to the apical disc, but do not reach the surface, being roofed over by the lateral extension of the plates of columns 3 and 4 (seen diagrammatically in fig. 7). Oculars all reach the periproct and pores exist in oculars H and J (p. 89). Genitals have three or four pores each. A few polygonal periproctal plates are in place, a very rare feature to be preserved and the only case known in this genus (p. 343).

Fig. 7. Diagrammatic section of areas H, I, and J, drawn in the line of the arrow in fig. 6. Ambulacral plates bevel over the interambulacral plates of columns 1 and 2, which are occluded from the surface by the lateral extension of the plate sof columns 3 and 4. The occluded plates marked X and *are the same plates as those that are similarly marked in fig. 6. (Compare Plate 39, fig. 5.)



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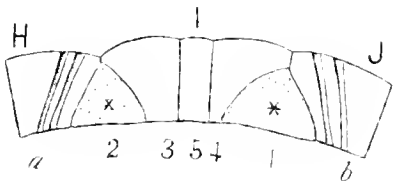

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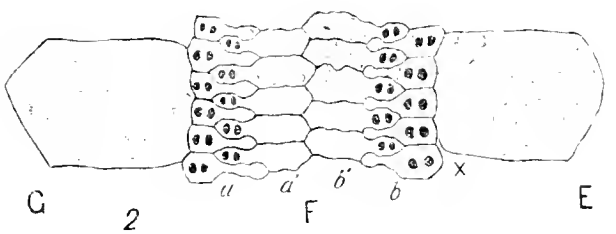

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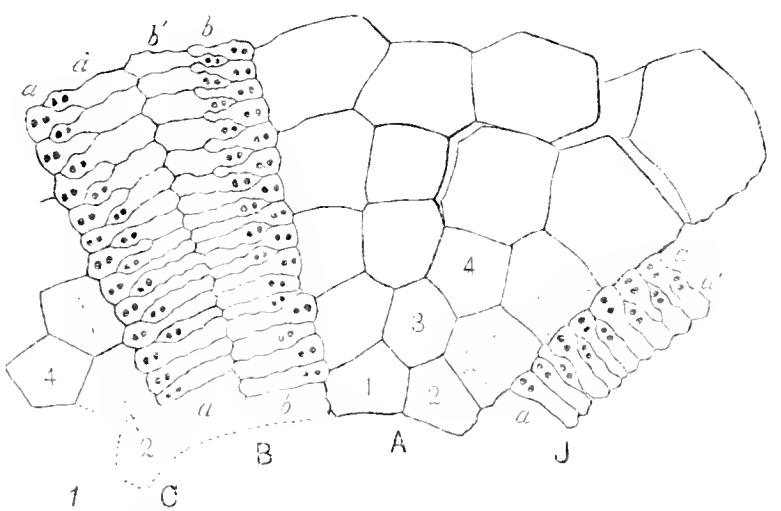

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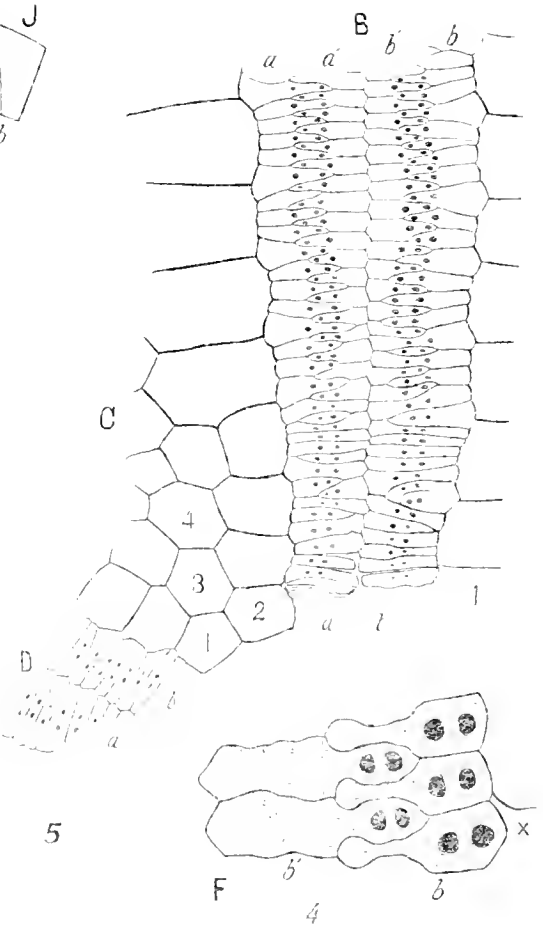

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PLATE 43.

Lovenechinus missouriensis (Jaekson). Page 337.

Figs. 1–5. Same specimen as the photographs of an internal and external mold, Plate 44, figs. 3 and 4 (pp. 344–346).

Fig. 1. Drawn from a wax cast of the external mold. × 2.6. Ambulacral plates ventrally are all primaries with pore-pairs uniserial; higher up plates are alternately primaries and nearly or quite occluded (seen better in Plate 42, fig. 1). Dorsally, plates are demi- and occluded, the pore-pairs biserial. In all ambulacral plates the pores lie near the interambulacral suture; tubercles are numerous, of uniform size. In all interambulacral areas there are two plates in the basicoronal row, three plates in the second, and four plates in the third row, the fifth column coming in later in the sixth or seventh row. In area I the initial plate of column 5 is tetragonal, a rare variation, and to compensate for the two sides wanting in this plate there are two heptagonal plates, H, lying on its left and right ventral border (compare the similar condition in the introduction of the ninth column in Oligoporus, Plate 50, figs. 2, 3, and Meloncchinus, Plate 59, fig. 14).

Fig. 2. Drawn directly from the internal silicified mold, representing the interior of the same plates of which fig. 1 shows the exterior. × 2.6. Ambulacral plates ventrally are all primaries; at the zone XX in area J, plates are alternately primaries and occluded; whereas on the exterior at the same zone, the plates are demi- and occluded (p. 60). Plates opposite interambulacral sutures are fan-shaped, which is not true of the exterior. Pore-pairs are in the middle of the half-area, whereas they are near the interambulacral suture on the exterior. Interambulacral plates are similar to the same plates of the external view, but are somewhat dislocated.

Fig. 3. Drawn from a wax cast of the external mold at the mid-zone, representing the detail of a half-ambulacrum and the tenth and eleventh plates from the base of the adradial column of area I. × 2.6. Ambulacral plates are demi- and occluded, pore-pairs are near the interambulacral suture, small tubercles are on all plates. (Compare text-fig. 11, p. 54.)

Fig. 4. Drawn directly from the internal mold, representing the interior of the same plates as fig. 3. × 3. Pore-pairs are in the middle of the half-area; demi-plates which are opposite the interambulacral horizontal sutures are fan-shaped (p. 60).

Fig. 5. Drawn from a point in the specimen where the internal and external molds are in place and the former mass of the original plates exists as cavities. × about 5. On the exterior, tubercles are in place, ambulacral plates bevel over the adradials. The pores of ambulacral plates are represented by delicate siliceous rods which pass from the middle of the half-area proximally to near the interambulacral suture distally, a unique condition of preservation.

Oligoporus (?) **minutus** Beede. Page 450.

Fig. 6. Deer Creek Limestone, Carboniferous (Coal Measures), northeast of Topeka, Kansas (after Beede, 1899, Plate 32, fig. 3). Holotype. × 0.9

Figs. 1–5 drawn by J. Henry Blake; fig. 6 copied by W. M. Barrows.

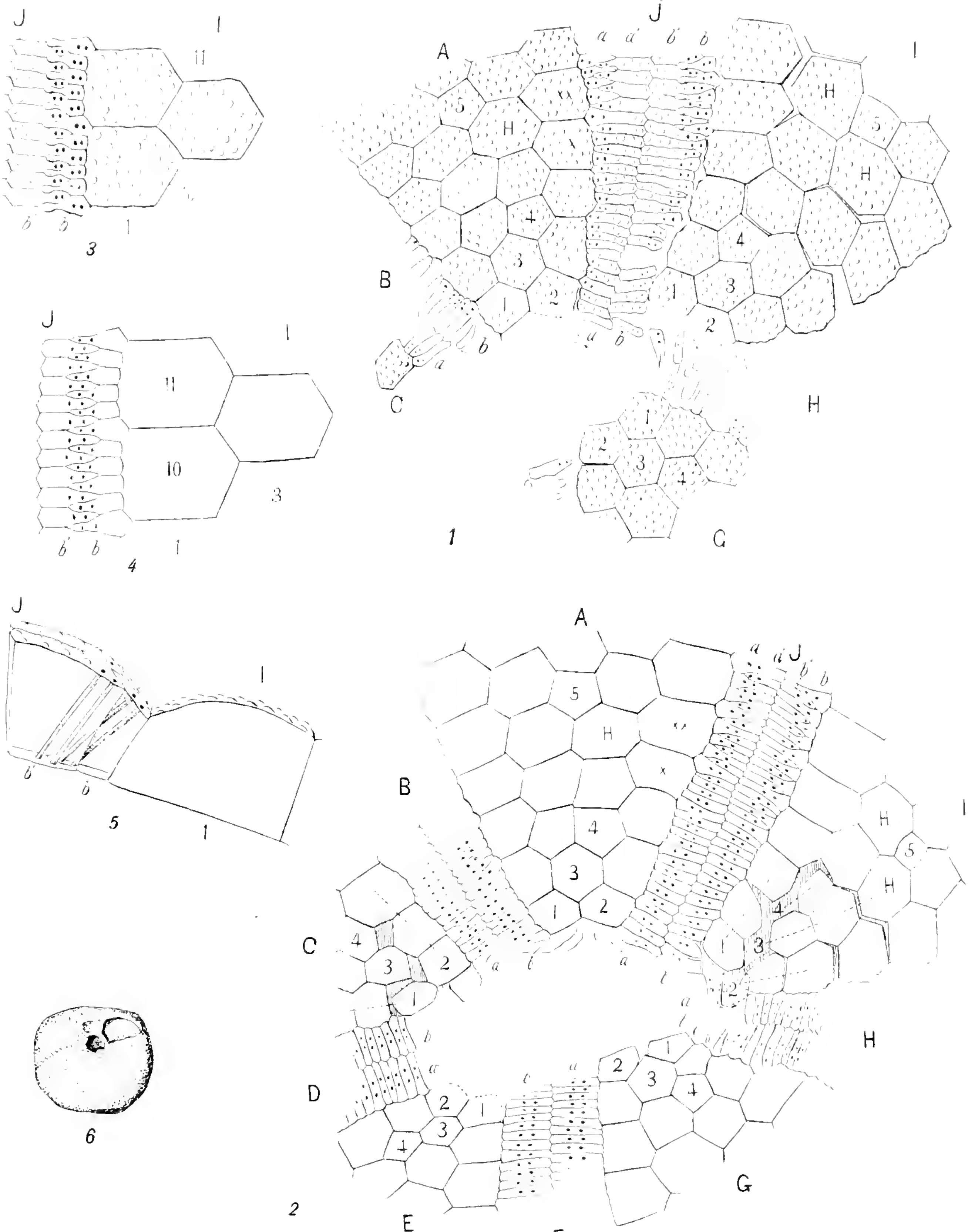
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PLATE 44.

Lovenechinus missouriensis (Jackson). Page 337.

Fig. 1. Burlington Group, Lower Carboniferous, Webb City, Missouri. Mus. Comp. Zoöl. Coll., 3,136 (from R. T. J. Coll.). Natural size. A moderate sized individual of uncompressed spherical form. There are five columns of plates in each of the five interambulacral areas; orally imperfect impressions of the lantern are in place.

Fig. 2. Burlington Group, Lower Carboniferous, Coriscana, Missouri. Yale Mus. Coll., 314. Natural size. Internal mold of medium sized specimen. Five columns of plates in each interambulacral area, oculars (not shown in the figure) all insert (p. 344).

Fig. 3. Burlington Group, Lower Carboniferous, Webb City, Missouri. Mus. Comp. Zoöl. Coll., 3,125 (from R. T. J. Coll.), paratype. Natural size. Internal siliceous mold, with boundaries of plates marked by more or less elevated ridges and pores by siliceous styles. Five columns of plates in each interambulacrum. In area A, there are two plates in the basicoronal row, three plates in the second row, four plates in the third row, and five plates in the sixth row. A heptagonal plate lies ventrally on the right of the initial plate of column 5 as usual, excepting in area I in which the initial plate of column 5 is tetragonal with two associated heptagonal plates as shown in Plate 43, figs. 1, 2. Drawings, Plate 43, figs. 2, 4, and 5 (pp. 344–346).

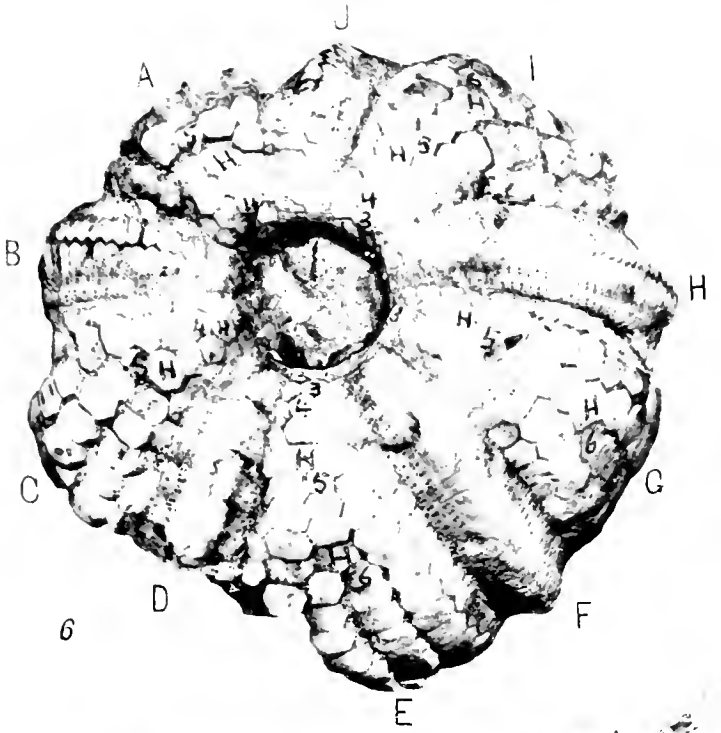
Fig. 4. Same specimen. Natural size. External siliceous mold, with impressions of plates, tubercles, etc. This specimen consisting of an external and an internal mold, presents a condition and perfection of preservation of parts that are unique in Palaeozoic Echini. Drawings, made from wax casts of this external mold, Plate 43, figs. 1 and 3, are compared directly with those made from the internal mold, Plate 43, figs. 2 and 4. The specimen is therefore drawn as if viewed in optical section for comparison of internal and external characters (p. 345).

Fig. 5. Same horizon and locality. Mus. Comp. Zool. Coll., 3,128 (from R. T. J. Coll.). Natural size. External siliceous mold, with outlines of plates and tubercles as impressions (p. 346).

Lovenechinus septies sp. nov. Page 348.

Fig. 6. Warsaw Group, Lower Carboniferous, Boonville, Missouri. F. Springer Coll., 8,115 (from G. Hambach Coll.), holotype. Enlarged, × 1.5. An exceptionally perfect specimen for the Palaeozoic, ventral view. The interambulacral columns as introduced by pentagonal plates with associated heptagonal plates, are marked on the specimen in ink.

Fig. 7. Same specimen enlarged, × 1.5. Dorsal view. Drawings of this specimen, Plate 45, figs. 1–6.



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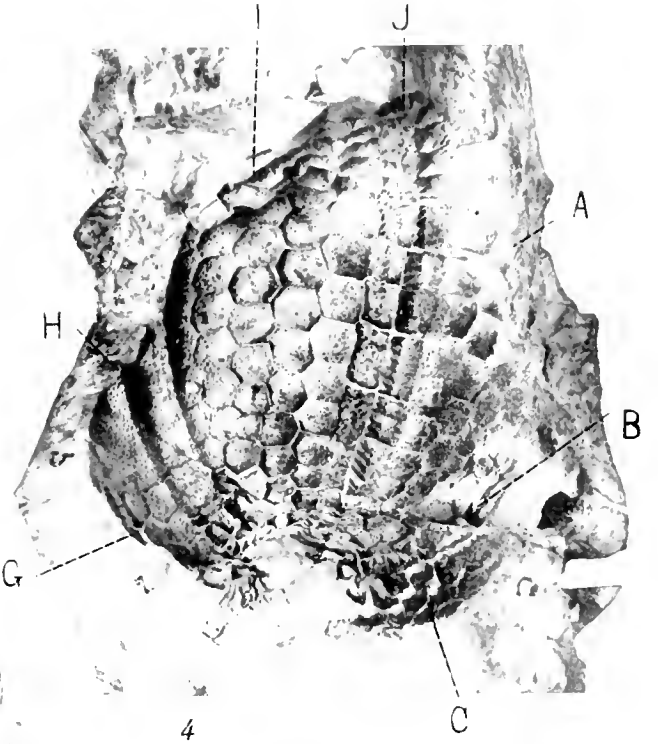

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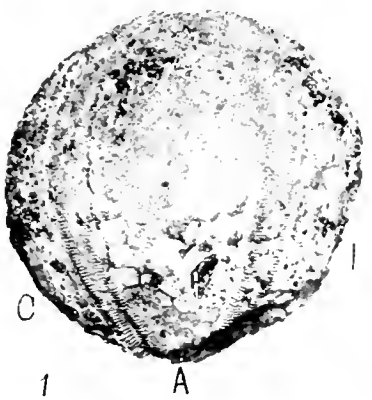

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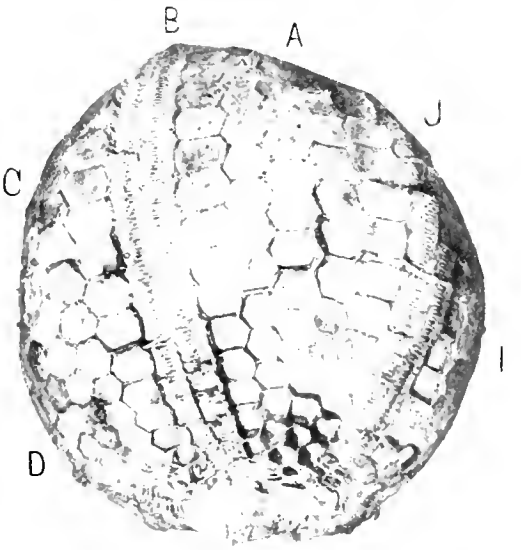

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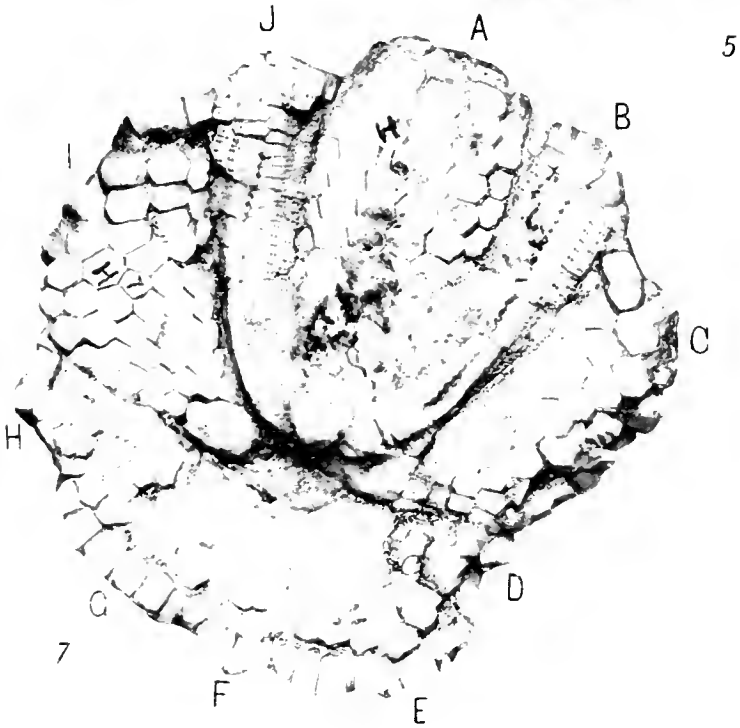

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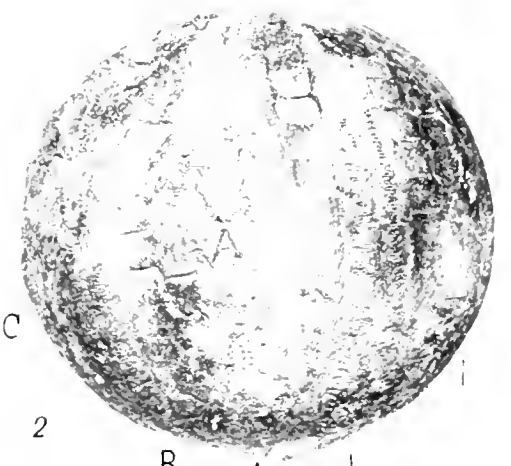

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PLATE 45.

Lovenechinus septies sp. nov. Page 348.

Figs. 1–6. Same specimen as photographs, Plate 44, figs. 6 and 7. Holotype.

Fig. 1. Specimen drawn spread out on the Lovén method. × 1.5. Ambulacral plates ventrally are all primaries, pore-pairs uniserial; at the mid-zone plates are demi- and occluded, with pore-pairs biserial. The interambulacra are remarkably perfect, but are restored partially as indicated by dotted lines. There are in each interambulacrum two plates in the basicoronal row, three plates in the second row, and four plates in the third row, excepting area C, in which, by rare exception, the fourth column does not originate until the fourth row. The initial plate of column 3 is hexagonal as usual in four areas, but in area C it is pentagonal (p. 68). Column 5 originates in the middle line of each area, in the sixth row in four areas, but in the seventh row in area C. Column 6 originates at or below the ambitus, and on the right of the center in areas A and G; but on the left of the center in areas C, E, and I. Column 7 originates above the ambitus and in the center line of each area. A heptagonal plate lies on the left or right ventral border of the initial plate of each column above the fourth. In area E there is an extra heptagon, H, due to an exceptional pentagonal plate, P, in column 6. Ocular and genital plates are in place dorsally.

Fig. 2. Shows primary ambulacral plates ventrally, which are succeeded by demi- and occluded plates. The ventral developing stages of the ambulacrum are not as complete as in the lower species *Lovenechinus missouriensis*, Plate 42, fig. 1. In the interambulacra the ventral developing stages are shown in two areas. × 4.4. (Compare text-fig. 17, p. 59.)

Fig. 3. Section of ambulacrum at the mid-zone. Pore-pairs biserial in peripodia; the suture line of the occluded and demi-plates is serrate, not tongue-like as in *L. missouriensis*, Plate 42, fig. 2. × 4.4.

Fig. 4. Showing primary ambulacral plates next the apical disc and an ocular plate covering the ambulacrum and laterally the interambulacra in part on either side. × 4.4.

Fig. 5. Section looking ventrally, showing the relative thickness of plates and ambulacrals beveled over the adambulacrals on the adradial sutures. Interambulacral plates are shaded for contrast. × 3.

Fig. 6. Genital and ocular plates with the dorsal contact of the coronal plates against the same. × 4.5.

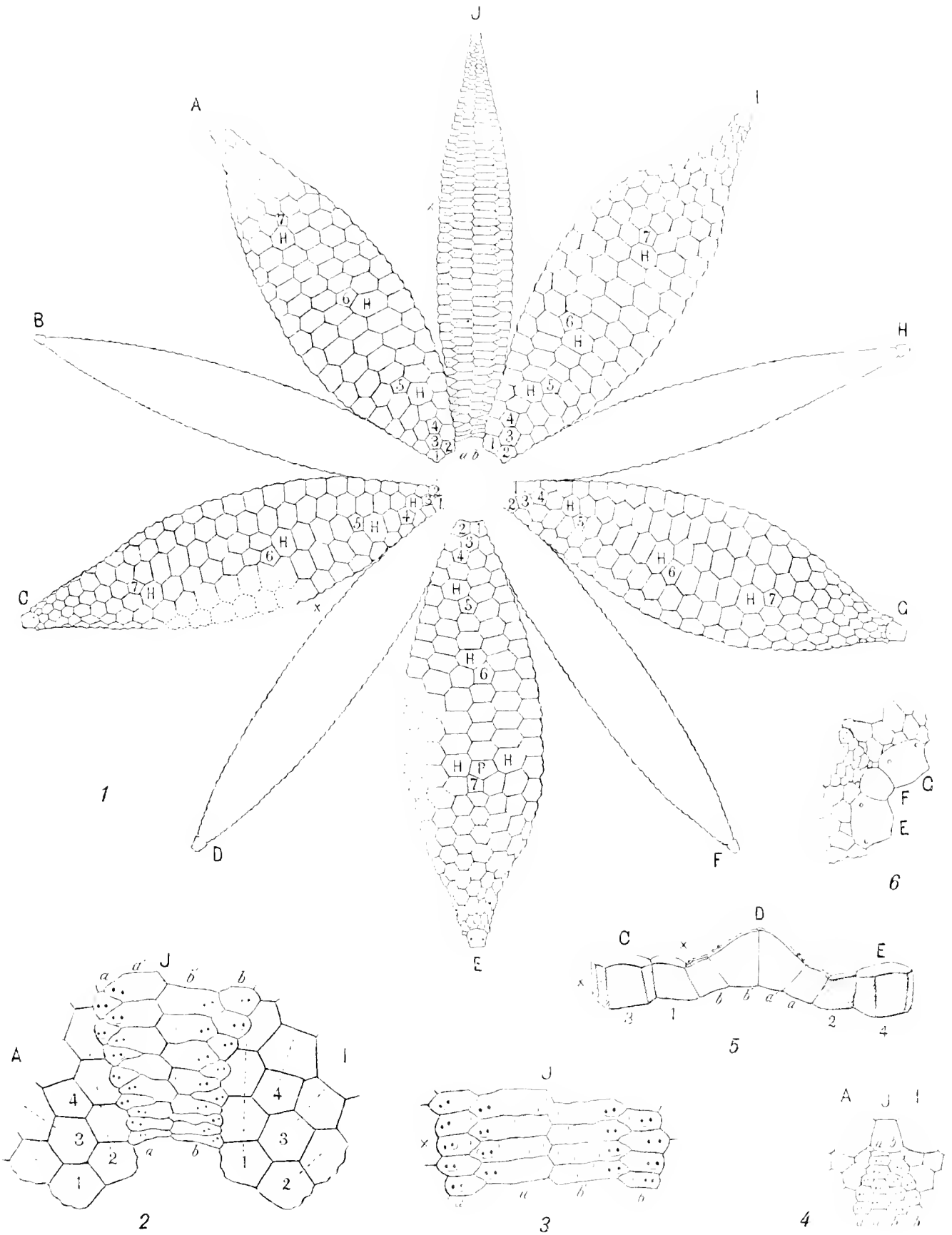
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PLATE 46.

Maccoya gigas (M'Coy). Page 321.

Figs. 1, 2. Arenaceous shale, Lower Carboniferous, Rahan's Bay, Dunkineely, County Donegal, Ireland. Griffith Collection, Science and Arts Museum, Dublin. Cotype. Natural size. Original of M'Coy's, 1844, Plate 24, fig. 1. In fig. 1, the obverse side, are parts of an ambulacrum and three columns of interambulacral plates. In fig. 2, the reverse side, the plates are flattened back like a hinge on the line of the adradial suture; in this view parts of two columns of interambulacral plates are in place, with in addition some dissociated plates. Drawing, after Baily, Plate 47, fig. 2.

Fig. 3. Same horizon, locality, and museum. Cotype. Natural size. Original of M'Coy's, 1844, Plate 44, fig. 4b. Two interambulacral plates. Surface ornamentation very clear.

Lovenechinus missouriensis (Jackson). Page 337.

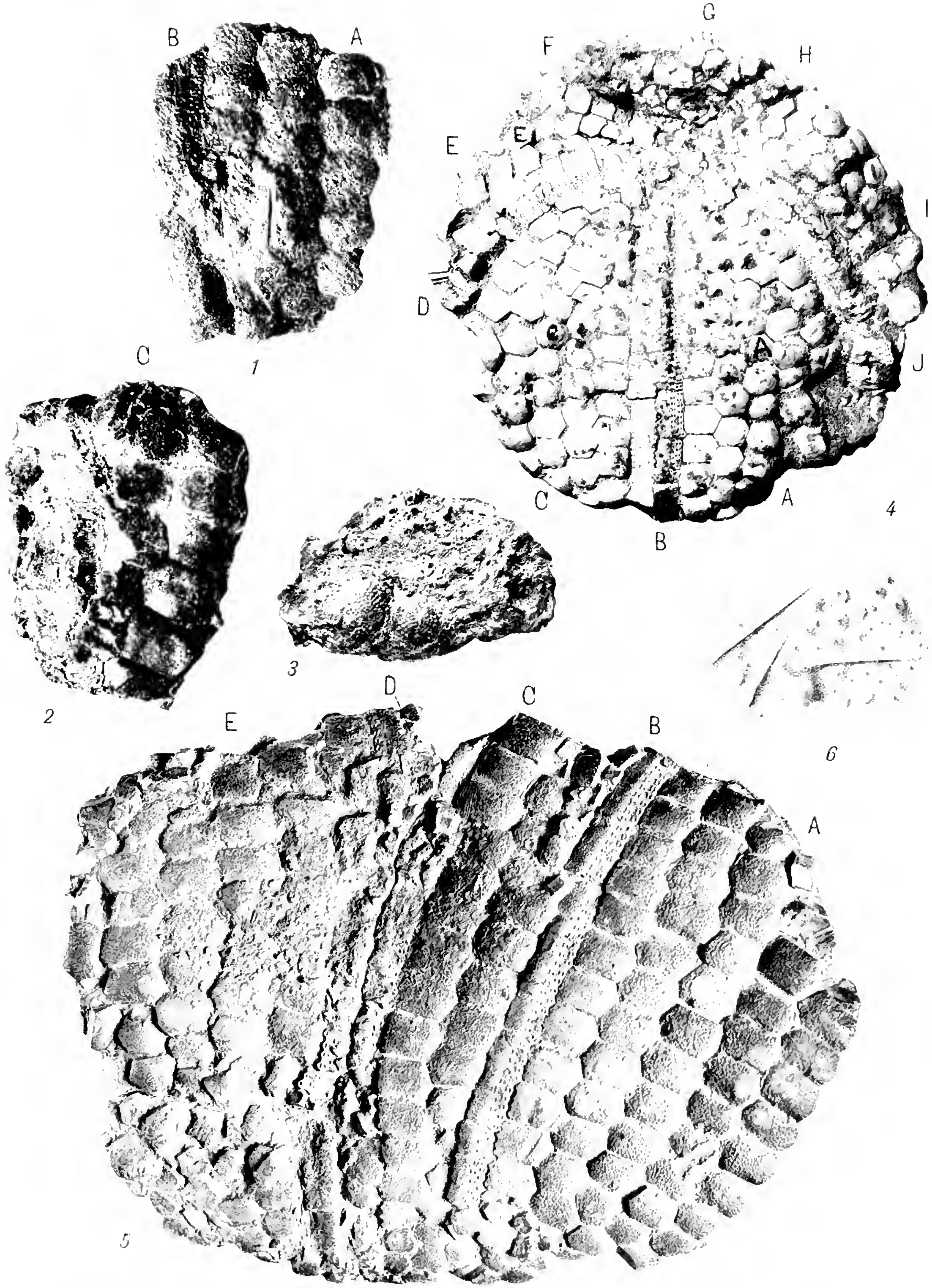
Fig. 4. Upper Burlington Limestone, Lower Carboniferous, Burlington, Iowa. F. Springer Coll., 8,126. Natural size. One of only two specimens of this species known from other than Missouri localities. Ambulacral detail very clear. Five columns of plates in each interambulacral area. Drawings, Plate 12, figs. 1–4 (p. 340).

Lovenechinus anglicus sp. nov. Page 346.

Fig. 5. Lower Carboniferous Limestone, Clitheroe, Lancashire. Museum of Practical Geology Coll., London, 6,576, holotype. Natural size. Ambulacrum B represents the right half of its area; ventrally plates are alternately primary and occluded; higher up and for most of the area, the plates are alternately demi- and occluded. Ambulacrum D represents ventrally a fragment of the left half of its area, and farther dorsally the whole width of the area somewhat imperfectly. Interambulacral plates are very large, but relatively thin. For further description see drawings, Plate 47, figs. 3–5.

Fig. 6. The same specimen. Interambulacral plate showing tubercles and spines. × 3

Figs. 1–3 from photographs taken by A. C. Bridle, in Dublin; fig. 5 by J. W. Tutcher; fig. 4 by H. W. Tupper; fig. 6 drawn by G. C. Chubb.



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Maccoya gigas (M'Coy). Page 321.

Fig. 1. Lower Carboniferous, Rahan's Bay, Ireland. Sedgwick Museum Coll., Cambridge, England, 3 (drawn from the original specimen of Keeping's, 1876, Plate 3, fig. 13). × 4.7. Ambulacral plates are alternately primaries and occluded, pore-pairs biserial.

Fig. 2. After Baily, 1877, Plate 3, fig. C. Same specimen as photograph, Plate 46, fig. 1. Cotype. × 1.6 All ambulacral plates reach the middle of the area, but alternate plates are primaries, meeting the interambulacrum, or occluded plates, which are cut off from interambulacral contact; pore-pairs biserial.

Lovenechinus anglicus sp. nov. Page 346.

Fig. 3. Same specimen as Plate 46, fig. 5. Holotype. × 0.9. This specimen, well preserved in many points, presents a curious case showing how parts may be shifted about. Interambulacrum A and the right half of ambulacrum B are quite complete; the left half of ambulacrum B and a large part of interambulacrum C are pushed to the right under the adjacent areas. In interambulacrum A there were at least six columns of plates; column 2 is assumed as indicated by dotted lines. In ambulacrum B ventrally the plates are primary and occluded, seen also ventrally in area D; higher up the plates are all demi- and occluded. This specimen is apparently the original of that which was described and figured by Duncan, 1889, p. 198, text-fig. 1, as *Palaechinus gigas*. Further, it is the original which I described and figured as *Palaechinus gigas* (see Jackson, 1896, p. 204, Plate 7, figs. 38, 39).

Fig. 4. Same specimen. Ambulacral plates from the ventral region. × 3.5. All plates meet the middle of the area, but alternate plates are primaries, meeting the interambulacrum and occluded, which are cut off from interambulacral contact. Compare Plate 42, fig. 1

Fig. 5. Same specimen, ambulacral plates from near the mid-zone. ×. 3.6. The occluded plates alone meet the middle of the area, demi-plates are narrower, laterally meeting the interambulacrum, and on their inner border fit between the outer ends of the occluded plates in a tongue-like fashion.

Oligoporus blairi Miller and Gurley. Page 351

Fig. 6. Same specimen as photograph, Plate 48, fig. 1. × 2.3 The holotype of *Oligoporus bullulus* Miller and Gurley, here considered a synonym of *blairi*. Ambulacrum with four columns of plates, demi- and occluded, also scattered isolated plates near the middle line of the half-areas. In area A there are four columns of interambulacral plates, a case of extreme arrested radial variation; in another area, C, of this specimen, which is only preserved dorsally, there are seven columns of interambulacral plates. Tubercles and spines are shown on one interambulacral plate

Fig. 7. Same specimen as photograph, Plate 49, fig. 1 Cotype of O. blairi. × 2.4 Section just above the mid-zone, ambulacrum with occluded, demi-, and scattered isolated plates, seven columns of plates in interambulacrum A.

Oligoporus coreyi Meek and Worthen. Page 353.

Fig. 8. Same specimen as photograph, Plate 48, fig. 2. Holotype. × 2.4. Section of an interambulacrum at the mid-zone showing six columns and the initial plate of a seventh column with its adjacent heptagon.

Fig. 9. Same specimen and areas at the mid-dorsal portion. × 2.3. Interambulacral columns have dropped out to five, ambulacrum with wide occluded, proportionately rather wide demi-, and scattered isolated plates.

Oligoporus sulcatus Miller and Gurley. Page 351.

Fig. 10. Same specimen as photograph, Plate 48, figs. 3, 4. Holotype. × 2.3. Section near the mid-zone, ambulacrum with occluded, demi-, and scattered isolated plates, seven columns of interambulacral plates in area I; the initial pentagon of column 7 with its adjacent heptagon appears in this view. Only the left half of ambulacrum II is shown, and as the sutures of plates are obscure they are in part shown by dotted lines.

Oligoporus halli sp. nov. Page 355.

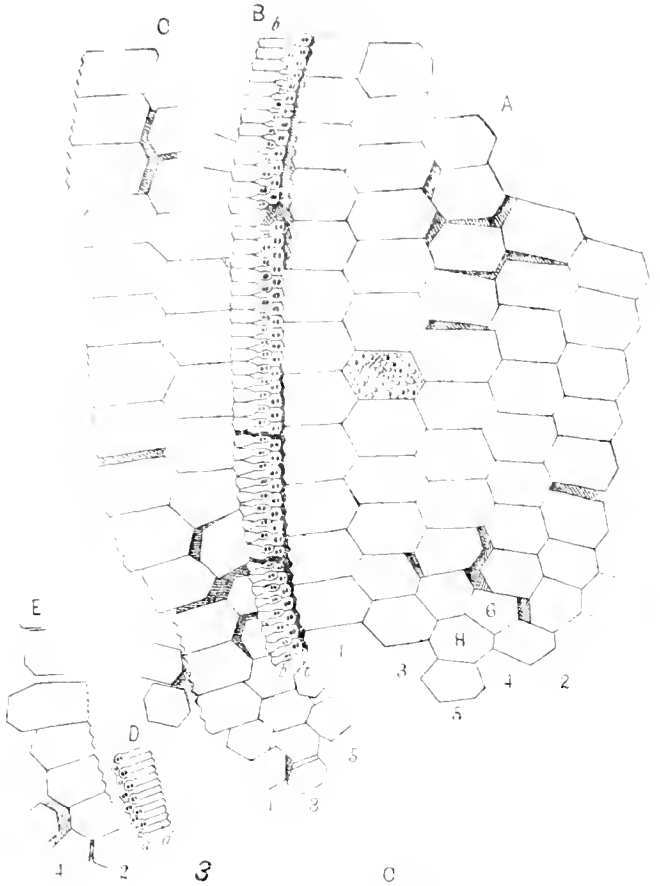
Fig. 11. Same specimen as photograph, Plate 48, fig. 5. Holotype. × 0.9. The ambulacrum near the mid-zone with occluded, demi-, and scattered isolated plates; eight columns of plates in interambulacral area C. In interambulacrum A the first two rows are restored as indicated by dotted lines. Column 3 originates in the second row, column 4 in the third row, and column 7 to the left of the center. In area C column 8 originates at about the mid-zone.

Fig. 12. Same specimen; enlargement of ambulacral detail. × 2.3.

Oligoporus danae (Meek and Worthen). Page 356.

Fig. 13. Keokuk Group, Lower Carboniferous, Jersey County, Illinois. F. Springer Coll. 8,124. × 2.3. Plates with spines in place.

Figs. 1, 2, 6–13 drawn by J. Henry Blake; figs. 3–5 by G. C. Chubb.



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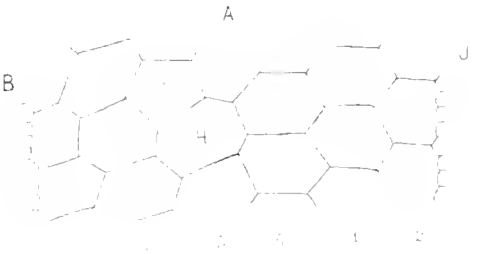

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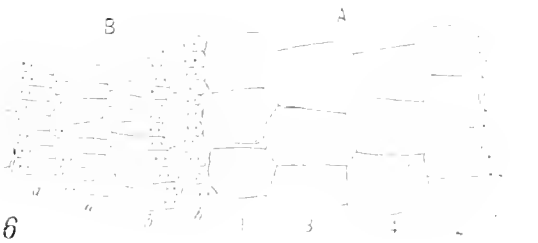

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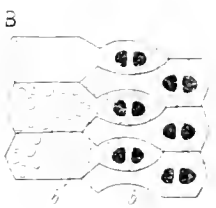

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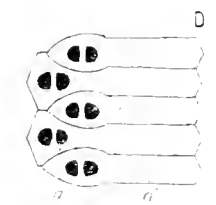

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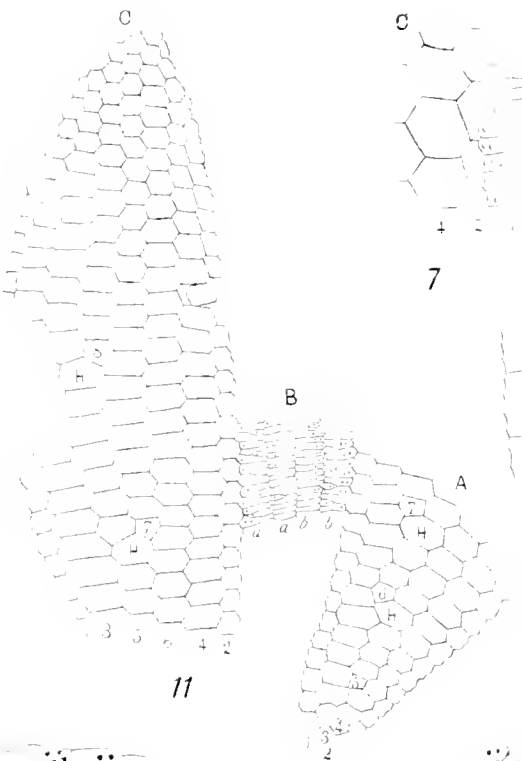

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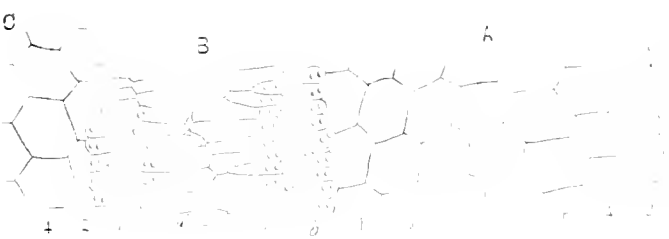

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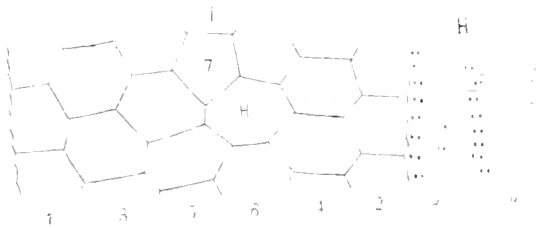

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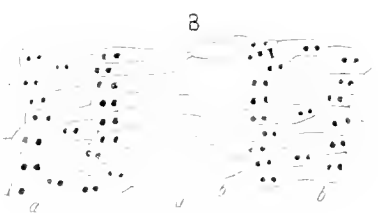

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PLATE 48.

Oligoporus blairi Miller and Gurley. Page 351.

Fig. 1. Keokuk Group, Lower Carboniferous, Boonville, Missouri. Univ. of Chicago Coll., 6,190 (the holotype of *Oligoporus bellulus* Miller and Gurley, here considered a synonym of *blairi*). Natural size. Ambulacral plates at the mid-zone are demi- and occluded, with scattered isolated plates. In interambulacrum A there are only four columns of plates, an extreme radial arrested variation; interambulacrum C is only preserved dorsally, but at that zone there are seven columns of plates in this area. Some tubercles and spines are in place on ambulacral and interambulacral areas. Drawing, Plate 47, fig. 6.

Oligoporus coreyi Meek and Worthen. Page 353.

Fig. 2. Keokuk Group, Lower Carboniferous, Crawfordsville, Indiana. Univ. of Michigan Coll., 147, holotype. Natural size. Dorsal view; the specimen is silicified, and the surface is worn, so that details are clear only in parts. Ambulacra with demi-, occluded, and scattered isolated plates. In interambulacra A, E, and G, there are seven columns of plates, but in C there are only six columns. In area I only six columns are visible but the area is imperfect dorsally. Drawings, Plate 47, figs. 8, 9.

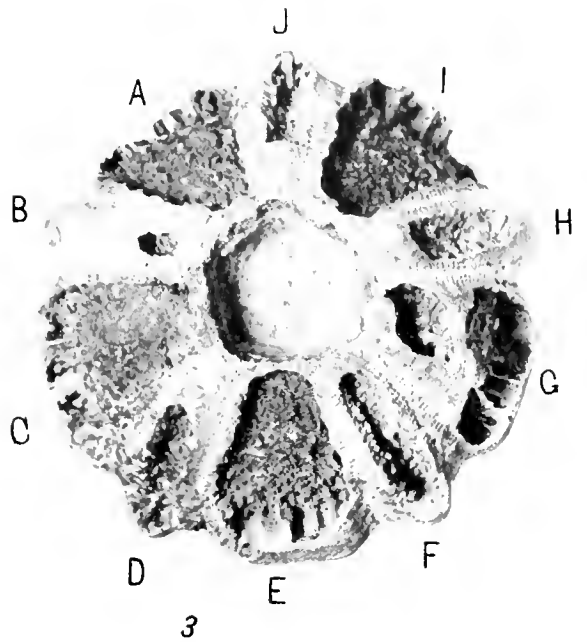
Oligoporus sulcatus Miller and Gurley. Page 354.

Fig. 3. St. Louis Group, Lower Carboniferous, Hardin County, Kentucky. Univ. of Chicago Coll., 6,623, holotype. Natural size. Silicified specimen, ventral view.

Fig. 4. Same specimen, dorsal view. Natural size. Melon-like ribs are strongly marked. Ambulacra with demi-, occluded, and scattered isolated plates. All interambulacra with six columns of plates at the mid-zone, but with a seventh arising just above that zone in each area. Drawing, Plate 47, fig. 10.

Oligoporus halli sp. nov. Page 355.

Fig. 5. Keokuk Group, Lower Carboniferous, Boonville, Missouri. F. Springer Coll., 8,114, holotype (from G. Hambach Coll., the original of Miss Klein's 1904, Plate 1, figs. 3a, 3b). Natural size. Melon-like ribs moderately developed. Ambulacra with demi-, occluded, and scattered isolated plates. Interambulacra A, C, and I each have eight columns of plates, but E and G have only seven. Drawings, Plate 47, figs. 11, 12.



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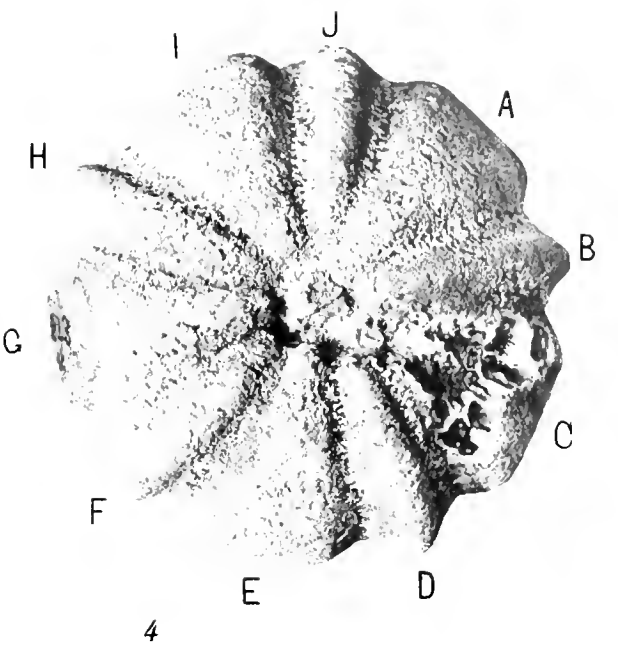

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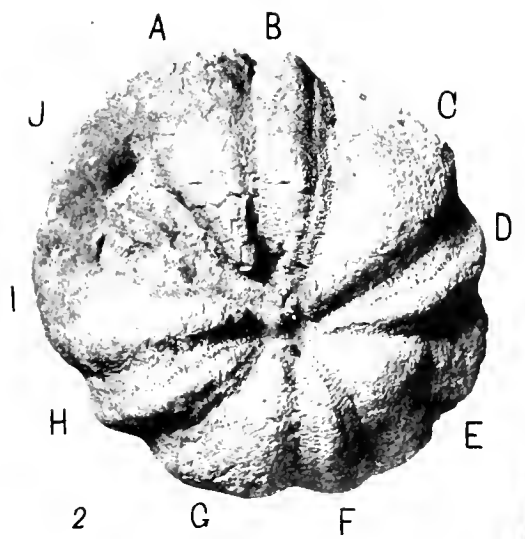

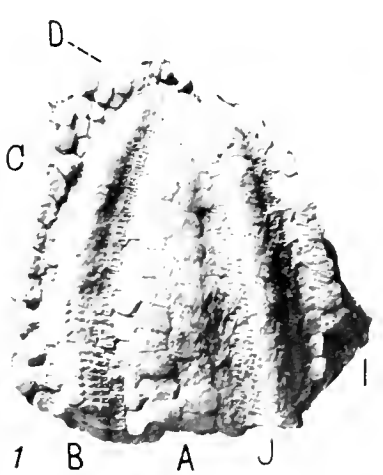

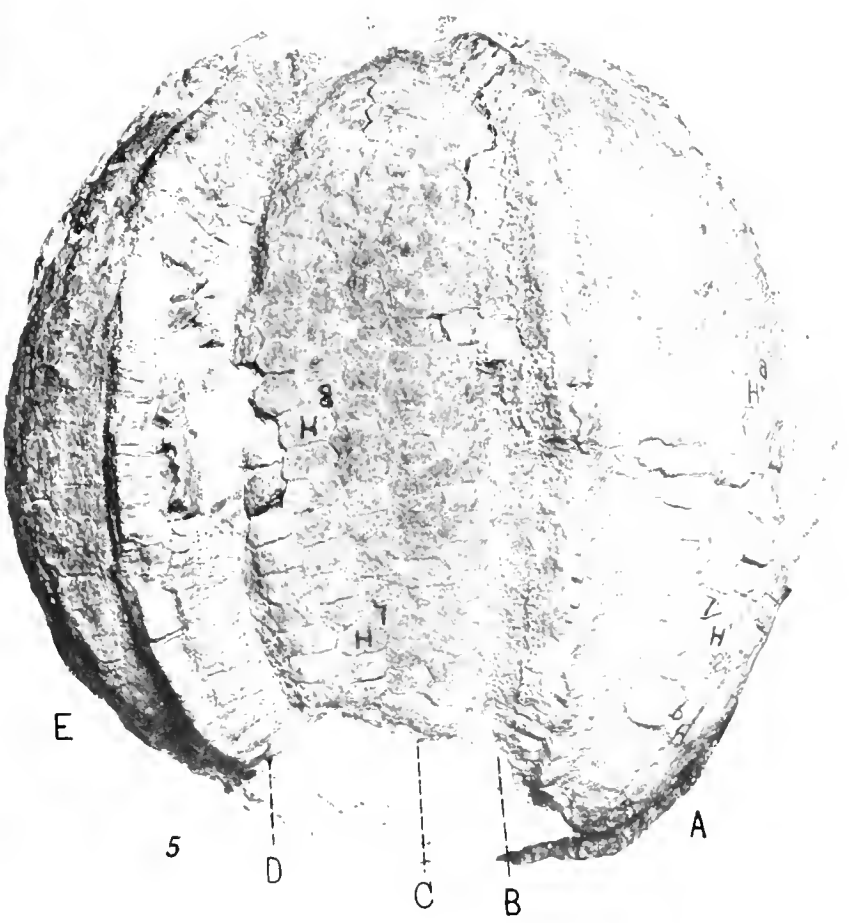

J. A. SAUNDERSON PHOTO

HELIOTYPE CO. BOSTON

PLATE 49.

Oligoporus blairi Miller and Gurley. Page 351.

Figs. 1–3. Keokuk Group, Lower Carboniferous, Boonville, Missouri. Univ. of Chicago Coll., 6,470, cotypes. Natural size. Melon-like ribs moderately developed, ambulacral plates demi-, occluded and scattered isolated.

Fig. 1. Interambulcra A, C, and E each with seven columns of plates. Drawing of this specimen, Plate 47, fig. 7.

Fig. 2. In interambulacrum A there are six columns of plates, the initial pentagon of column 6 lying on the right of the center just below the mid-zone. In interambulacrum C there are seven columns of plates. The initial pentagon of column 5 is in the middle line near the ventral border; the initial pentagon of column 6 lies three rows above on the left of the center, and the initial pentagon of column 7 lies again three rows above in the center and just above the mid-zone.

Fig. 3. In interambulacrum A there are six columns of plates, the initial pentagon of column 6 with a heptagon on its right ventral border lying on the left of the center and below the mid-zone. In interambulacrum C the initial pentagon of column 6 lies on the left of the center and appears somewhat earlier than in area A. The initial pentagon of column 7 with a heptagon on its right ventral border appears just above the mid-zone. Above this zone on the right the plates are displaced and confused.

Oligoporus danae (Meek and Worthen). Page 356.

Fig. 4. Keokuk Group, Lower Carboniferous, Adams County, Illinois. Mus. Comp. Zool. Coll., 3,142 (from R. T. J. Coll.). Natural size. Ambulacra with demi-, occluded, and scattered isolated plates. Interambulacra with nine columns of plates in each area, the ninth appearing at the mid-zone. Drawing, Plate 50, fig. 1.

Fig. 5. Same specimen, reverse side. Natural size. Both interambulacra with nine columns of plates. Drawings, Plate 50, figs. 2–6.

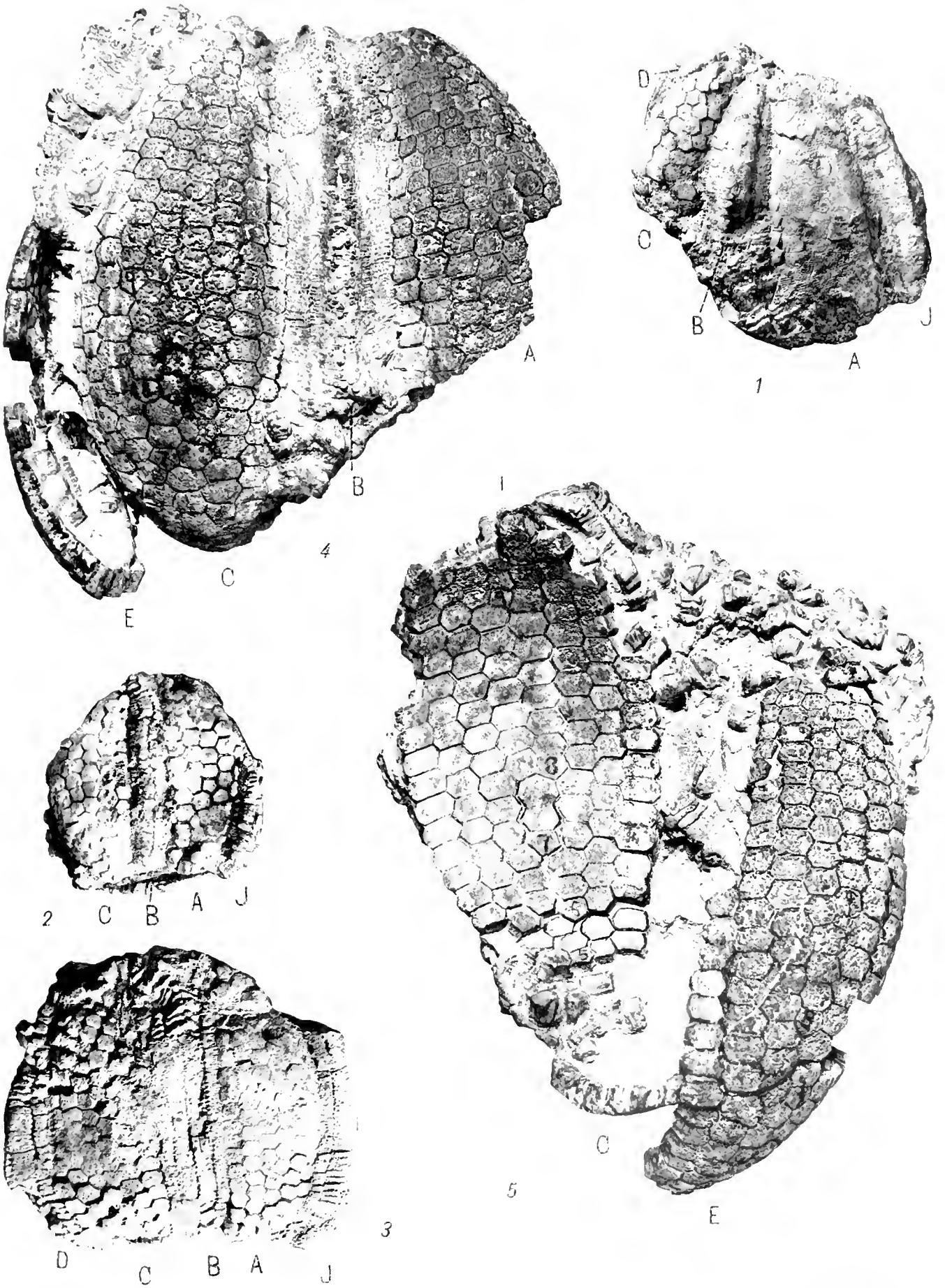
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PLATE 50.

Oligoporus danae (Meek and Worthen). Page 356.

Fig. 1. Same specimen as photograph, Plate 49, fig. 4. × 0.8. Restored ventrally as indicated by dotted lines; ambulacrum at the mid-zone with occluded, demi-, and scattered isolated plates. Interambulacra each with nine columns of plates, the ninth originating at or below the mid-zone.

Fig. 2. Same specimen and view as the photograph, Plate 49, fig. 5. × 0.8. External view of interambulacrum E. The adradial plates show lateral beveling where, when in place, they are inclined over by the ambulacral plates (compare Plate 45, fig. 5). The ninth column originates in a tetragonal plate, the two wanting sides of which are compensated for by two ventrally adjacent heptagonal plates.

Fig. 3. Same specimen and view as the photograph, Plate 49, fig. 5. × 0.8. Internal view of interambulacrum I, restored ventrally as indicated by dotted lines. Curiously the ninth column originates in a tetragonal plate with two adjacent heptagons as in area E (fig. 2). It is rare for the initial plates of columns as introduced to be tetragonal but a similar case is shown in the ninth column in Meloncchinus, Plate 59, fig. 14, and in the fifth column in Lovenechinus, Plate 43, fig. 2.

Fig. 4. Same specimen; left half-ambulacrum from the area marked X, in fig. 1. × 2.5. Demi-plates are wide, but the occluded are wider, with scattered isolated plates.

Fig. 5. Same specimen; right half-ambulacrum, from another area at the mid-zone. × 2.5.

Fig. 6. Same specimen; genital plate with two oculars restored as indicated by dotted lines. × 2.5. The genital plate has a strong bevel on its adoral face so that it is distinctly higher on the interior than it is on the exterior.

Fig. 7. Keokuk Group, Lower Carboniferous, Keokuk, Iowa. Mus. Comp. Zoöl. Coll., 2,998. × 2.4. Ambulacrum from the mid-zone, demi-plates are wide, but the occluded are wider, scattered isolated plates. (Compare text-fig. 12, p. 54; also compare figs. 1, 7, and 8 with text-fig. 237, p. 231.)

Fig. 8. Keokuk Group, Lower Carboniferous, Washington County, Indiana. F. Braun Coll. × 2.5. Ventrally ambulacral plates are primaries only; higher up a few plates are primary and occluded; higher still demi- and occluded, but as yet no isolated plates have appeared. In the interambulacra there are two plates in the basicoronal row, three plates in the second row, and four plates in the third row, the fifth column originating in the fifth row; a few tubercles and spines are shown in area A.

Fig. 9. Same specimen. × 2.5. Left half-ambulacrum from a higher zone, showing the typical generic character with isolated plates in the middle of the half-area.

Fig. 10. Keokuk Group, Lower Carboniferous, Jersey County, Illinois. F. Springer Coll., 8,124. × 3.3. Interambulacral plate with secondary tubercles.

Fig. 11. Lower Carboniferous, Missouri. Mus. Comp. Zoöl. Coll., 3,146 (from R. T. J. Coll.). × 2.5. Pyramid in side view, with ridges for the attachment of interpyramidal muscles.

Fig. 12. Same slab; pyramid. × 2.5. An internal view, showing the dental slide, pyramidal suture, and an epiphysis in place.

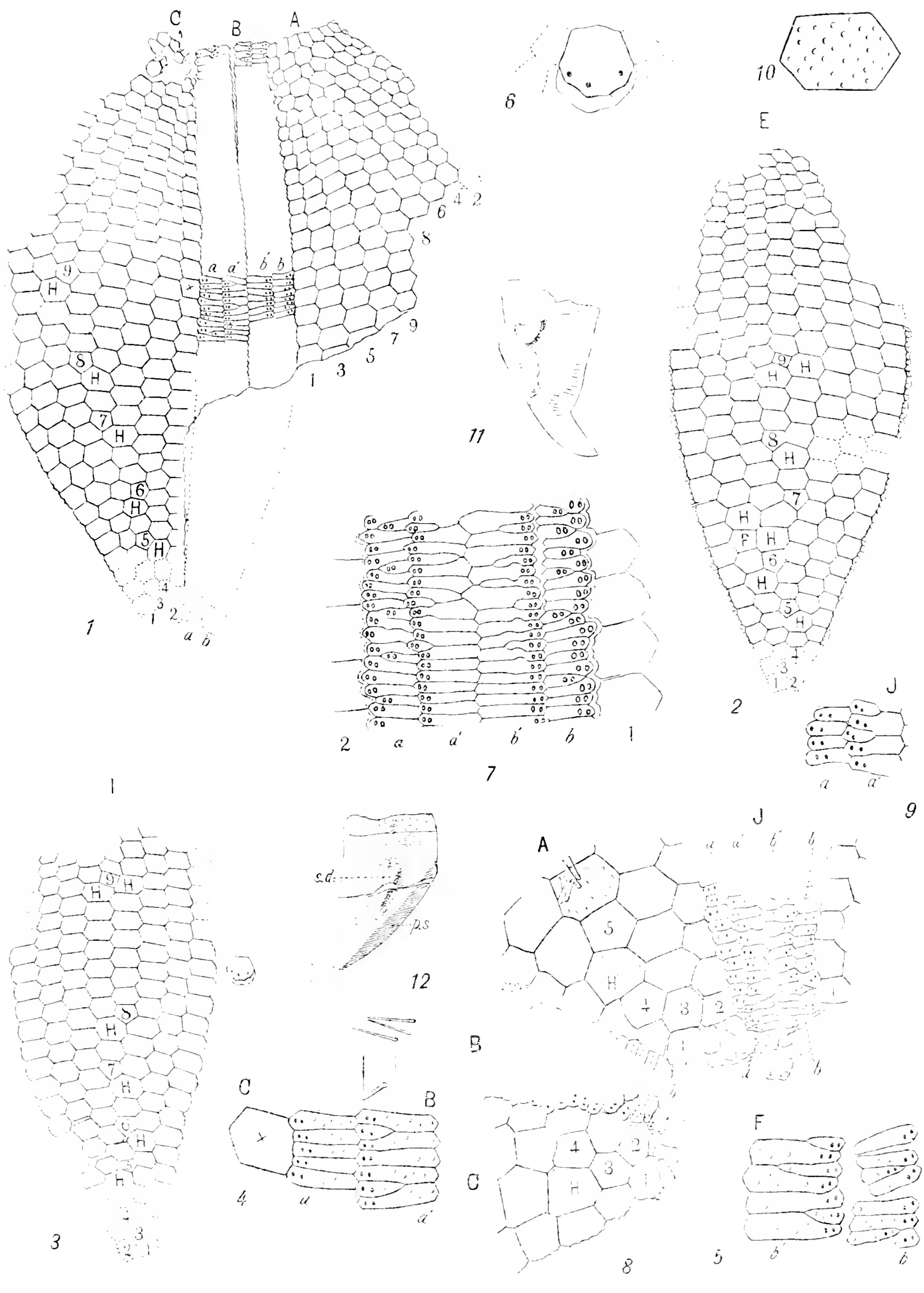
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PLATE 51.

Melonechinus dispar (Fischer von Waldheim). Page 365.

Figs. 1-3. Lower Carboniferous Limestone, Ratofka, Moscow, Russia, after Fischer von Waldheim, 1848, Plate 3, figs. 4a-4d. Holotype.

Fig. 1. Probably magnified × 2. Six columns of plates in the ambulacral areas and four columns of plates in the interambulacrum; structurally the simplest species known in the genus.

Fig. 2. Ambulacral plates enlarged; they are more hexagonal than in any specimens of other species seen.

Fig. 3. Single interambulacral plate with tubercles. Enlarged.

Melonechinus parvus (Hambach) Page 365.

Fig. 4. Lower St. Louis Limestone, Lower Carboniferous, St. Louis, Missouri. F. Springer Coll., 8,118, holotype (from G. Hambach Coll.). Natural size. Ventral view, melon-like ribs are weakly marked; six columns of plates in each ambulacral area at the mid-zone and six columns of plates in interambulacrum A at a point a little dorsal to the mid-zone. Drawing, Plate 52, fig. 1.

Melonechinus springeri sp. nov. Page 366.

Fig. 5. St. Louis Group, Lower Carboniferous, Elizabethtown, Kentucky. F. Springer Coll., 8,103, holotype. Natural size. A small species, with melon-like ribs strongly marked, six columns of plates in an ambulacral area at the mid-zone. In interambulacra E, G, and I there are six columns of plates, but in interambulacra A and C a seventh column is represented by a few plates dorsally. The apical disc measures proportionately about 23 % of the diameter of the test, which is relatively large for the genus and family (p. 367). Drawings, Plate 52, figs. 2-6.

Melonechinus crassus (Hambach). Page 367.

Fig. 6. Lower St. Louis Limestone, Lower Carboniferous, St. Louis, Missouri. F. Springer Coll., 8,116, holotype (from G. Hambach Coll., the original of Miss Klem's, 1904, Plate 1, figs. 2a-2d). Natural size. A massive species, with strong rounded melon-like ribs. There are eight columns of ambulacral plates at the mid-zone and six columns of interambulacral plates in areas A, C, E, and G, but area I is imperfect dorsally so that the number of columns is uncertain. In the figure, the oral area is below. Hambach's published figure of this specimen is inverted. Drawings, Plate 52, figs. 7-11.

Melonechinus indianensis (Miller and Gurley) Page 369.

Fig. 7. St. Louis Group, Lower Carboniferous, Greenville, Harrison County, Indiana. Univ. of Chicago Coll., 6,622, holotype. Natural size. Melon-like ribs strongly marked, a large, old-age individual. Eight columns of plates in an ambulacral area at the mid-zone. In interambulacra A to G there are six columns of plates, but in I there are seven columns and two plates representing an eighth column. The apical disc measures proportionately 16 % of the diameter of the test (p. 370). Oculars are all insert, genitals are wide and high. Drawings, Plate 53, figs. 1-4.

Fig. 8. St. Louis Group, Lower Carboniferous, Greenville, Harrison County, Indiana. F. Braun Coll. Natural size. There are six columns of plates in each interambulacral area. The apical disc measures proportionately 18 % of the diameter of the test.

Fig. 9. Lower Carboniferous, Allen County, Kentucky. Mus. Comp. Zool. Coll., 3,147. Natural size. Eight columns of plates in each ambulacral area, and six columns of plates in each interambulacral area. The sutures of the plates are a good deal obscured by silicification.

Melonechinus septenarius Jackson. Page 373.

Fig. 10. Warsaw Group, Lower Carboniferous, Buzzard's Roost, Franklin County, Alabama. Amer. Mus. Nat. Hist., [illegible], holotype. Natural size. The specimen is a siliceous internal mold, therefore the surface character is unknown; eight columns of plates in the ambulacral area at the mid-zone and seven columns of plates in the interambulacral area. Drawing, Plate 53, fig. 5.

Fig. 10 from photograph taken in New York; all others by F. A. Saunderson.

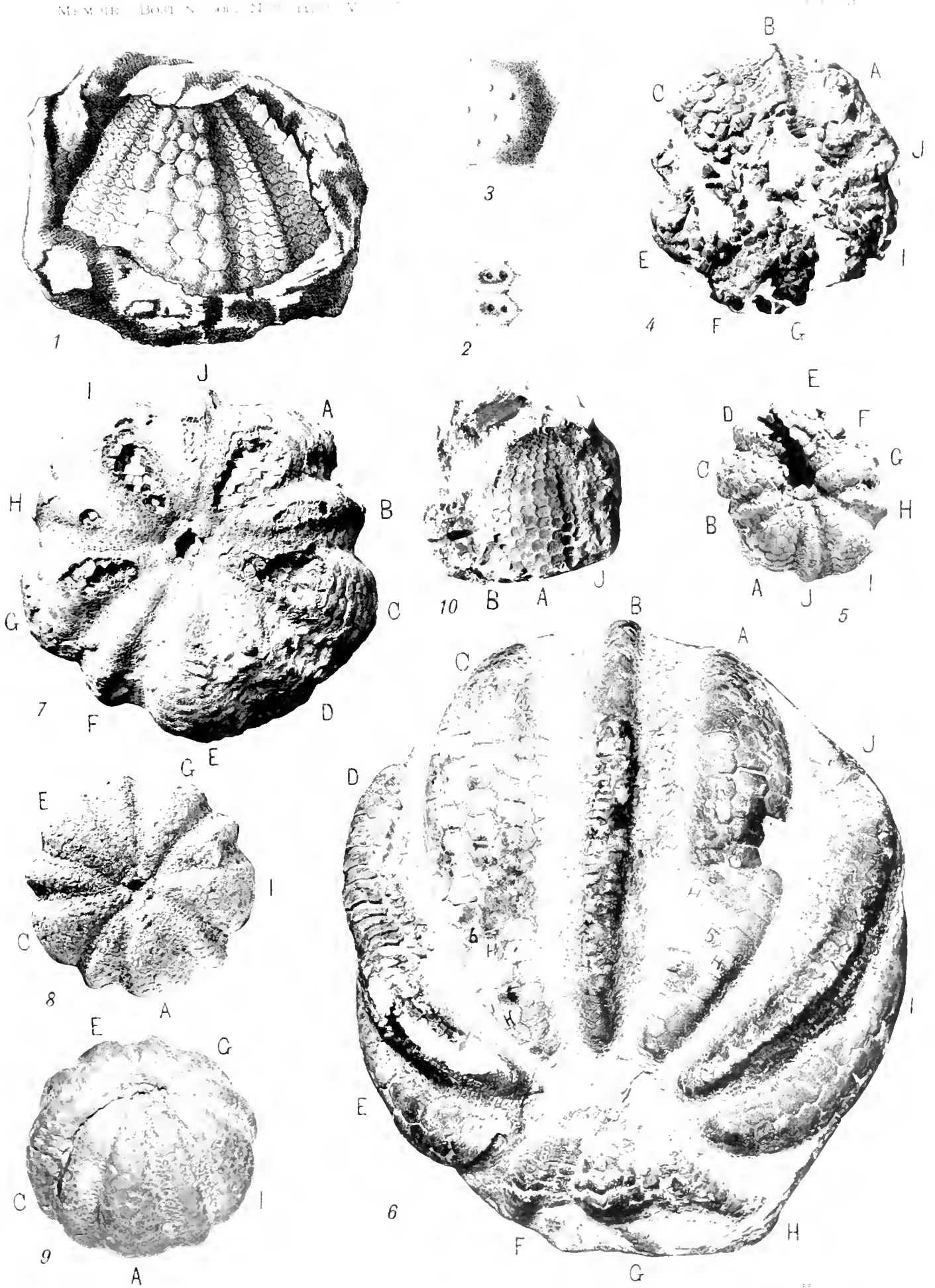
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PLATE 52.

Melonechinus parvus (Hambach). Page 365.

Fig. 1. Same specimen as photograph, Plate 51, fig. 4. Holotype. × 1.8. Six irregular columns of ambulacral plates at the mid-zone. In area B as far adorally as it is preserved there are two columns of plates, demi- and occluded in the right half-area, higher up dissociated isolated plates appear, higher again the isolated plates become more frequent and make a continuous column, thus forming with the demi- and occluded plates three columns in a half-area, the species character. In interambulacrum A (restored ventrally, as indicated by dotted lines) there are five columns of plates at the mid-zone. A sixth column appears dorsally represented by one pentagonal plate with a heptagon, H, on its left ventral border. In area C a peculiar pentagonal plate, X, appears in column 4, and the adradial plate on its right has six instead of five sides as is usual in the plates of an adradial column.

Melonechinus springeri sp. nov. Page 366.

Figs. 2–6. Same specimen as photograph, Plate 51, fig. 5. Holotype.

Fig. 2. Upper part of the test. × 3.6. In the half-ambulacra there are three irregular columns of plates at the mid-zone, higher up two columns with dissociated isolated plates, then two columns only and near the ocular one column only in a half-area. Interambulacrum with six columns of plates at the mid-zone, a seventh appearing dorsally in this area and also in area C. (Compare fig. 2 with text-fig. 19, p. 59; and figs. 2 and 3 with text-fig. 237, p. 231.)

Fig. 3. Half-ambulacrum ventrally. × 3.6. Two columns of demi- and occluded plates ventrally, higher up an isolated plate appears, then more isolated plates appear making three columns in the half-area.

Fig. 4. Interambulacrum I, restored ventrally, as indicated by dotted lines, showing the introduction of columns 5 and 6. × 1.8.

Fig. 5. Ambulacral plates, showing tubercles and pore-pairs in peripodia. × 7.

Fig. 6. Interambulacral plate with tubercles. × 7.

Melonechinus crassus (Hambach). Page 367.

Figs. 7–11. Same specimen as photograph, Plate 51, fig. 6. Holotype.

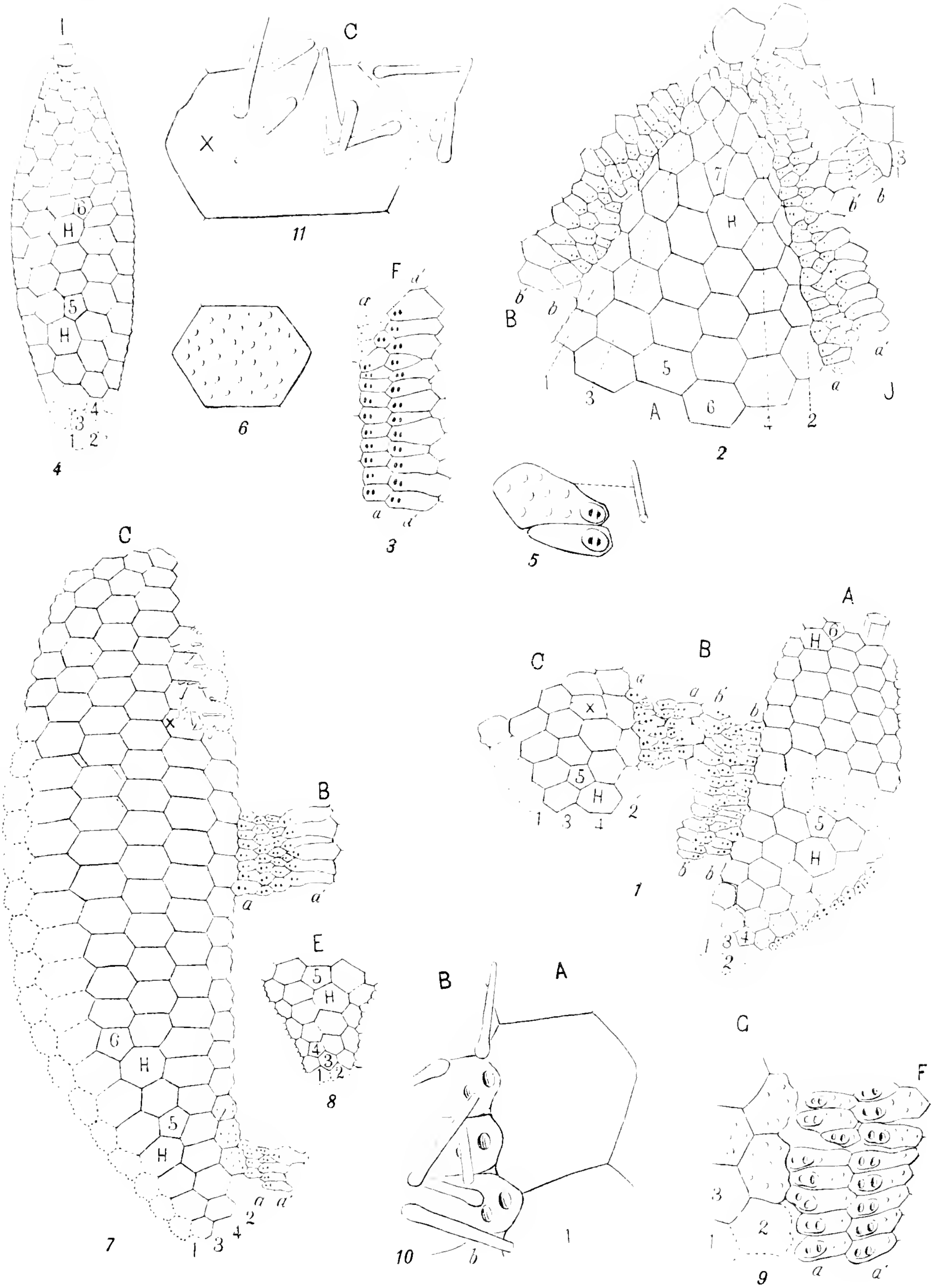
Fig. 7. Interambulacrum C with a half-ambulacrum at the mid-zone. × 1.3. Column 1 is partially restored, as indicated by dotted lines. Columns 5 and 6 originate early; ambulacrum with four columns of plates in the half-area at the mid-zone.

Fig. 8. Ventral part of interambulacrum E. × 1.3. The basicoronal row is restored, as indicated by dotted lines; there are three plates in the second row, and four in the third, the fifth column appearing in the seventh row.

Fig. 9. Base of ambulacrum F. × 3.5. Ventrally, there are demi- and occluded plates only, higher up isolated plates appear in the middle line of the half-area. Compare the ventral plates of ambulacrum B in fig. 7.

Fig. 10. Spines in ambulacrum B. × 7.2.

Fig. 11. Spines in interambulacrum C, from area marked X in fig. 7. × 7.1



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Melonechinus indianensis (Miller and Gurley). Page 369.

Figs. 1–4. Same specimen as photograph, Plate 51, fig. 7. Holotype.

Fig. 1. Dorsal portion spread out. × 3.4. In ambulacrum F there are four columns of plates in a half-area as far ventrally as it is shown and the number decreases passing dorsally to the apical disc. Interambulacral columns 1 and 2 drop out dorsally, indicating senescence, and some additional columns drop out as column 6 in area G and column 4 in area C. Ocular are all insert and adorally cover the ambulacra and laterally the interambulacra in part on either side. Three genital pores in one plate, and in the other genital plates the pores are partly or wholly obliterated by the process of silicification

Fig. 2. Ventral part of the left half of ambulacrum J. × 3.4. Ventrally the plates are all demi- and occluded; higher up isolated plates appear, then three columns, and at the top of the figure there are four columns in the half-area, the species character.

Fig. 3. Ambulacrum J at the mid-zone. × 3.4. Four columns of plates in a half-area; pore-pairs are in peripodia, tubercles on the interambulacral plates. (Compare figs. 1–3 with text-fig. 237, p. 231.)

Fig. 4. Interambulacrum I. × 0.8. Partially restored ventrally and on each side as indicated by dotted lines. In the basicoronal row there are two plates (restored), three plates in the second row, and four in the third, column 5 originating in the seventh row with a tetragonal plate, a rare occurrence, and to compensate for the two sides wanting there are two adjacent heptagonal plates, H, H. Column 6 originates two rows above the fifth with a pentagonal plate, with an adjacent heptagon on its left ventral border. The seventh column appears at the mid-zone, and an eighth column is represented by two plates. All other interambulacral areas of this specimen have six columns of plates.

Melonechinus septenarius (Jackson). Page 373.

Fig. 5. After Jackson, 1896, Plate 9, fig. 49. Same specimen as photograph, Plate 51, fig. 10. Holotype. × 1.3. There are four columns of plates in a half-ambulacrum, and seven columns of plates in an interambulacral area. The seventh column originates between columns 2 and 4, a peculiar exception.

Melonechinus stewartii (Safford). Page 371.

Figs. 6–8. Drawn from the original specimen which is an external mold, therefore the lettering of the figures is reversed. A photographic figure of a plaster cast of the type is shown in Plate 54, fig. 1, holotype.

Fig. 6. Half-ambulacrum near the mid-zone. × 3.5. Four columns of plates in the half-area; pore-pairs are in peripodia, tubercles on ambulacral and interambulacral plates.

Fig. 7. Spines. × 3.4.

Fig. 8. Dorsal half of interambulacrum G. × 0.9. Seven columns of plates in the area, the seventh appearing above the mid-zone.

Melonechinus obovatus sp. nov. Page 373.

Figs. 9, 10. Same specimen as photograph, Plate 54, figs. 2, 3. Holotype.

Fig. 9. Structure at the mid-zone. × 2.6. Five columns of irregular plates in an ambulacral half-area. As this is an internal mold, the pores do not lie near the interambulacrum (compare Plate 56, figs. 4, 5). Only three columns of plates occur in an interambulacral area, which is the fewest known as a species character in the genus or the family (pp. 417, 444).

Fig. 10. Dorsal view. × 2.6. Three columns of plates in each interambulacral area; impressions of insert ocular and genitals are all in place. The ocular adorally cover the ambulacra and laterally the interambulacra in part on either side.

Melonechinus liratus sp. nov. Page 374.

Fig. 11. Same specimen as photograph, Plate 54, fig. 4. Holotype. × 1.3. Section at the mid-zone, showing five columns of plates in an ambulacral half-area, and eight columns of plates in an interambulacral area.

Fig. 5 drawn by J. H. Emerton; all others by J. Henry Blake.

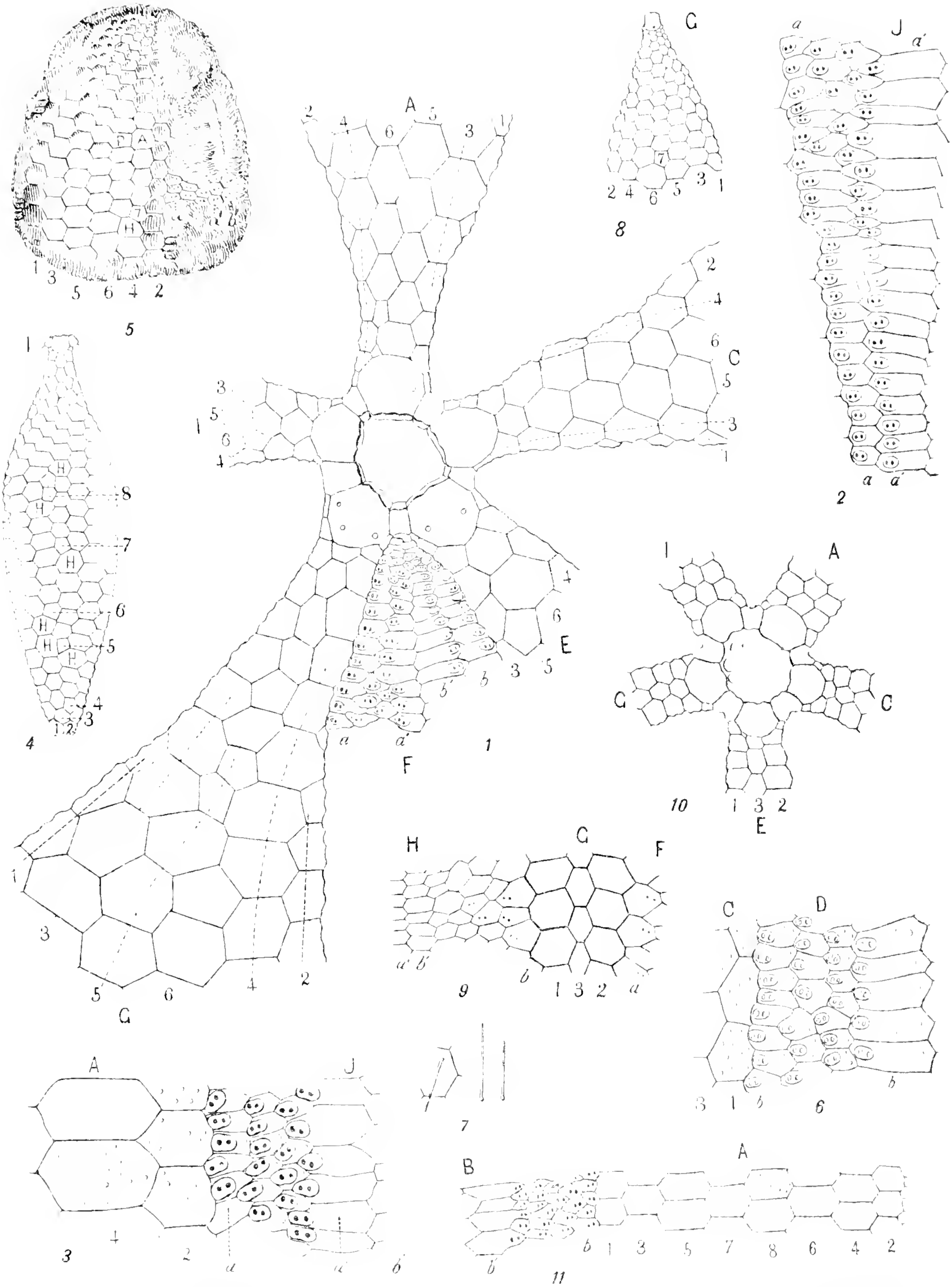
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PLATE 54.

Melonechinus stewartii (Safford). Page 371.

Fig. 1. Lower Carboniferous, probably St. Louis Group, Middle Tennessee, but the detailed locality is unknown. Plaster cast of the holotype, which is an external mold. Natural size. The holotype is in Vanderbilt Univ. Coll., 223. Eight columns of plates in an ambulacral area at the mid-zone. In each of the interambulacral areas A to G there are seven columns of plates, but in area I there are only six. The apical disc and periproctal plates are well preserved. The apical disc measures proportionately about 17% of the diameter of the test. Drawing from the original molds, Plate 53, figs. 6–8, or directly from a wax cast of same, Plate 56, fig. 1.

Melonechinus obovatus sp. nov. Page 373.

Figs. 2, 3. Lower Carboniferous. White's Creek, Davidson County, Tennessee. Vanderbilt Univ. Coll. Holotype. Natural size. The specimen is an internal calcite mold, so that the melon-like ribs, which are a feature of the exterior in most species of the genus, are unknown. Ten columns of plates in an ambulacral area at the mid-zone. In the interambulacra there are only three columns of plates in each area at the mid-zone, the fewest known in the genus or family.

Fig. 2. Side view, showing the peculiar obovate form, with the ambitus above the mid-zone, a very rare character in Echini (p. 32). Drawing, Plate 53, fig. 9.

Fig. 3. Dorsal view. No melon-like ribs shown, this being an internal mold; oculars and genitals are all in place. The apical disc measures proportionately 25% of the diameter of the test which is relatively very large for the genus (p. 374). Drawing, Plate 53, fig. 10.

Melonechinus liratus sp. nov. Page 374.

Fig. 4. Lower Carboniferous, locality unknown, but doubtless from Tennessee or Kentucky. Vanderbilt Univ. Coll., 221, holotype. Natural size. High, angular, melon-like ribs in ambulacral and interambulacral areas. Ten columns of plates in each ambulacral area and eight columns of plates in each interambulacral area. Drawing, Plate 53, fig. 11.

Melonechinus multiporus (Norwood and Owen). Page 375.

Fig. 5. St. Louis Group. Lower Carboniferous, St. Louis, Missouri. F. Springer Coll., 8,112 (from G. Hambach Coll., K 12, the original of Miss Klem's, 1901, Plate 5, fig. 12d; Plate 6, figs. 12a–12e). Natural size. Low rounded melon-like ribs. In area A there are nine, but in all other interambulacral areas eight columns of plates (p. 384). The introduction of the eighth column is seen adorally in areas C and E. Oculars and genitals are clear. Oculars are insert and are in contact with the interambulacra laterally as seen clearly in area D. Genital A has four genital pores and the other four genitals have three pores each (p. 379).

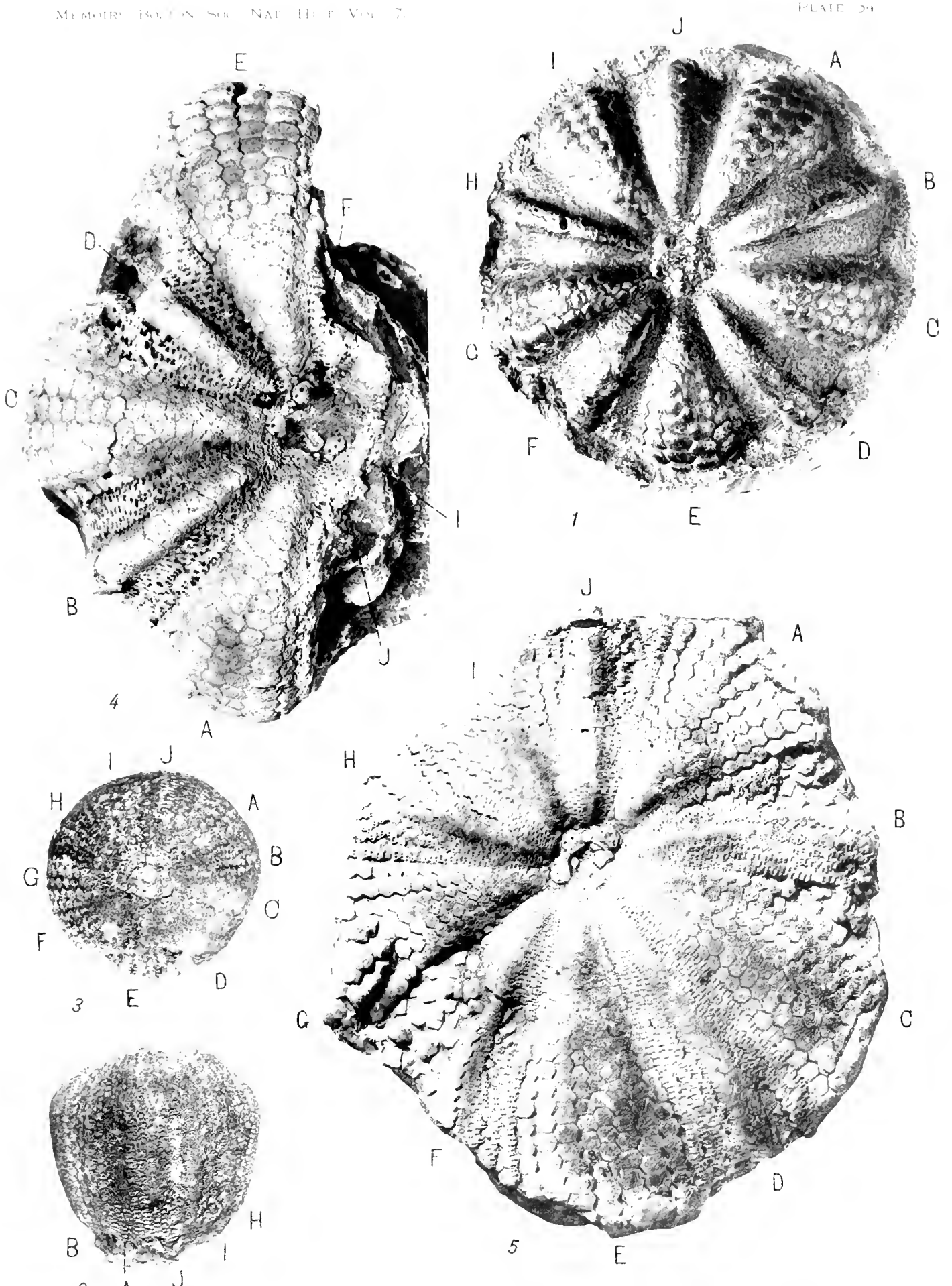
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PLATE 55.

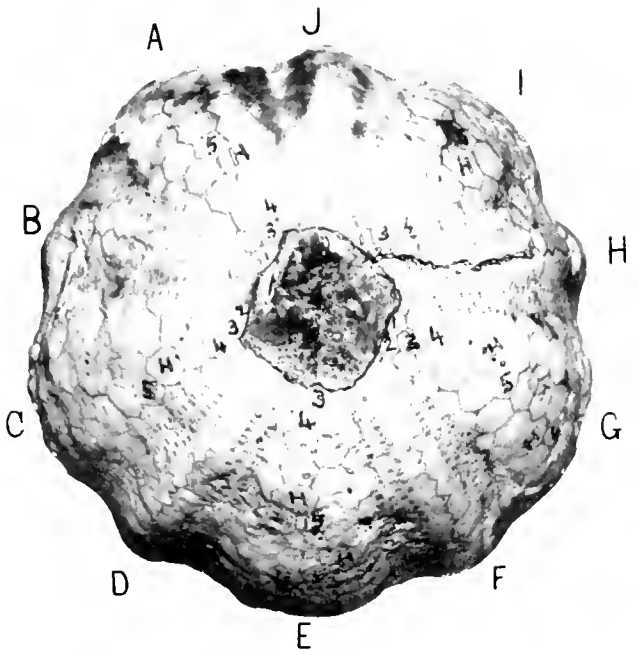
Melonechinus multiporus (Norwood and Owen). Page 375.

Figs. 1–3. St. Louis Group, Lower Carboniferous, St. Louis, Missouri.

Fig. 1. F. Springer Coll., 8,106 (from G. Hambach Coll., K 6, the original specimen of Miss Klem's, 1904, Plate 3, figs. 6a–6e). Enlarged × 1.2. Diameter through the plane J, E, 63 mm., height 57 mm. Ventral view, a small but marvellously perfect specimen. Melon-like ribs low, rounded. In four ambulacral areas the plates ventrally are in four columns there being two columns of demi-plates and two columns of occluded plates in each area as usual at this zone in the species and the genus, the number of columns in each area increasing in passing dorsally. As an exception in area B ventrally there are two primary plates representing two columns in this zone as a unique regressive radial variation. In interambulacrum G there are two plates in the basicoronal row, three plates in the second row, and four plates in the third row. The fifth column originates in the sixth row with a heptagon on the left border of the initial pentagon. The sixth column originates in the tenth row with a heptagon on the right of its initial pentagonal plate (compare Plate 57, fig. 1, and text-fig. 245, p. 382). The other interambulacral areas are similar except that the two plates of the basicoronal row are not complete in each area.

Fig. 2. The same specimen, dorsal view. Enlarged × 1.2. Eight columns of plates in each interambulacral area, and these plates dorsally approach a rhombic form. Insert ocular and genitals are all in place. The apical disc measures proportionately about 15% of the diameter of the test. Drawings of this exceptionally fine specimen, Plate 57, figs. 1–3; text-figs. 245, 246, p. 382. (See pp. 230, 376, 379, 381–384.)

Fig. 3. F. Springer Coll., 8,109 (from G. Hambach Coll., K 9, the original specimen of Miss Klem's, 1904, Plate 4, fig. 9d; Plate 5, figs. 9a, 9b). Natural size. An exceptionally large specimen, the largest seen of this species. There are nine columns of plates in interambulacral areas C, E, and G. Four oculars and all genitals are well preserved. Oculars are insert and cover the ambulacra and laterally the interambulacra in part on either side, as seen in several areas. Genital E has three, and G four pores; the other genitals have apparently three pores each, but the number may be four in one or more of these plates as confusing accessory pits exist. The apical disc measures proportionately about 15% of the diameter of the test (pp. 376, 377, 379).



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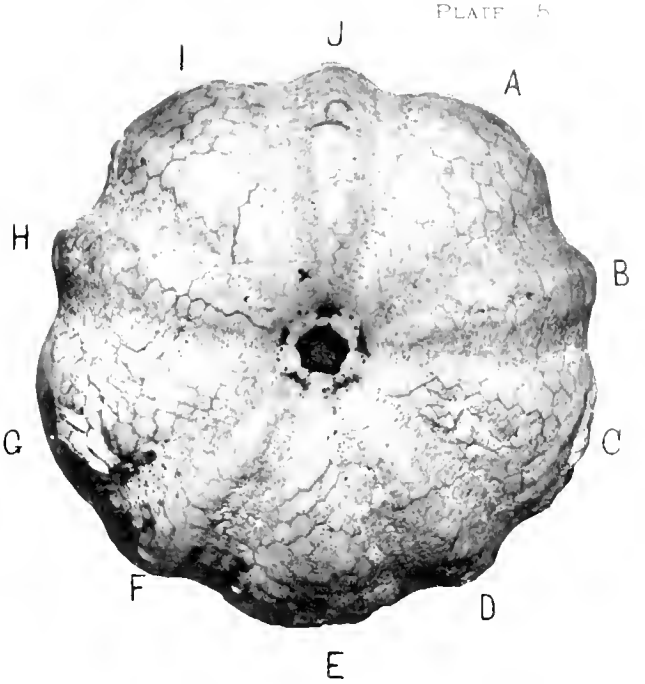

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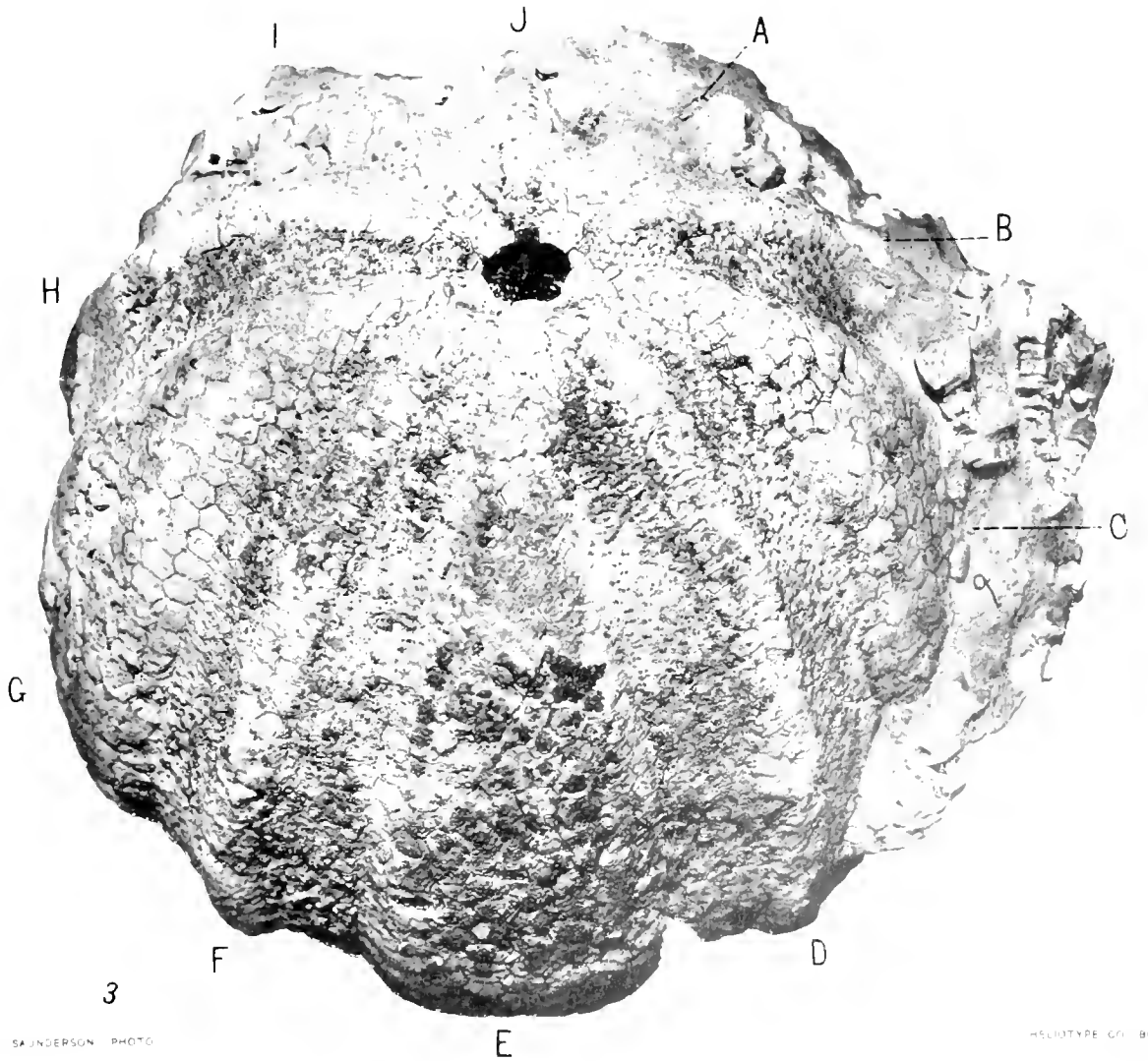

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A. SAUNDERSON PHOTO.

HELIOTYPE CO. BOSTON.

PLATE 56.

Melonechinus stewartii (Safford). Page 371.

Fig. 1. Same specimen as photograph, Plate 54, fig. 1. Drawn from a wax cast of the holotype which is an external mold. × 3.5. Oculars and genitals are all in place, and in addition a number of polygonal periproctal plates are in place. This is the only specimen known in the genus in which the periproctal plates are known (p. 363).

Melonechinus multiporus (Norwood and Owen). Page 375.

Figs. 2–13. St. Louis Group, Lower Carboniferous, St. Louis, Missouri.

Fig. 2. After Jackson and Jaggar, 1896, Plate 2, fig. 3. Mus. Comp Zool. Coll., 3,003. × 1.2. A nearly perfect ventral area. There are four columns of plates in three of the ambulacra; in each interambulacrum there are two plates in the basicoronal row and three plates in the second row (p. 376).

Fig. 3. After Jackson and Jaggar, 1896, Plate 2, fig. 4. Mus. Comp. Zool. Coll., 2,994. Development of an ambulacrum. × 3.5. Ventrally there are four columns consisting of demi- and occluded plates, higher up scattered isolated plates appear in the middle of each half-area, still higher there are three, then four irregular columns of plates in each half-area (pp. 228, 376).

Fig. 4. Vanderbilt Univ. Coll., 218. Ambulacrum at the mid-zone seen from the exterior. × 2.3. Ten irregular columns of plates consisting of two columns of wide occluded plates, two columns of narrow demi-plates, and six irregular columns of isolated plates. Pore-pairs lie in that portion of each plate nearest to the next adjacent interambulacrum (p. 376). (Compare text-figs. 13, p. 54; 20, p. 59; also compare Plate 56, figs. 2, 3, 4, and 6 with text-fig. 237, p. 231.)

Fig. 5. Mus. Comp. Zool. Coll., 3,164 (from R. T. J. Coll.). × 2.3. Ambulacrum at the mid-zone, seen from the interior (compare fig. 4). The two median columns of occluded plates are narrower than on the exterior. In the lateral columns of demi-plates those lying opposite the horizontal interambulacral sutures are fan-shaped, which they are not on the exterior (compare Plate 43, figs. 3, 4). The ambulacral pore-pairs of occluded plates lie near the outer margin of each plate; in isolated plates the pore-pairs lie near the middle of each plate and in demi-plates they lie toward the inner margin of each plate, instead of all toward the next adjacent interambulacrum, as they do in all plates, when seen on the exterior (pp. 60, 376).

Fig. 6. Mus. Comp. Zoöl. Coll., 3,158. (from R. T. J. Coll.). × 4.6. In ambulacrum J there are six columns of plates as far ventrally as shown, higher up there are four columns, and next the ocular only two plates, representing two columns, a primitive character (compare text-fig. 237, p. 231). Other ambulacral areas are similar, but with a less complete reduction dorsally. Young interambulacral plates are in contact with the oculars. Ocular plates are all insert and adorally cover the ambulacra and laterally the interambulacra in part on either side. Genitals with three pores each (pp. 376, 379, 381). (Compare text-fig. 163, p. 149.)

Fig. 7. Princeton Univ. Coll., 1,464. × 1.7. Showing peristomal plates, the only specimen known in the genus or family with this character preserved. In the ambulacrum of the peristome there are two plates in an area orally, these I consider as representing the primordial ambulacral plates, as seen in areas J and D; passing aborally, the plates increase to many low small irregular plates in each area on the periphery of the peristome. Interradially there are three non-ambulacral plates in an area: one adorally, and two in a row aborally. The base of the corona is quite perfect, with four plates in the basicoronal row of each ambulacral area and two plates in the basicoronal row of each interambulacral area (p. 378).

Fig. 8. The same restored, with teeth and pyramids (compare text-fig. 48, p. 80), (pp. 82, 85, 362, 378).

Fig. 9. Mus. Comp. Zool Coll., 3,165 (from R. T. J. Coll.). × 1.8. A pyramid, with its ventral portion and tooth restored as indicated by dotted lines (pp. 363, 379).

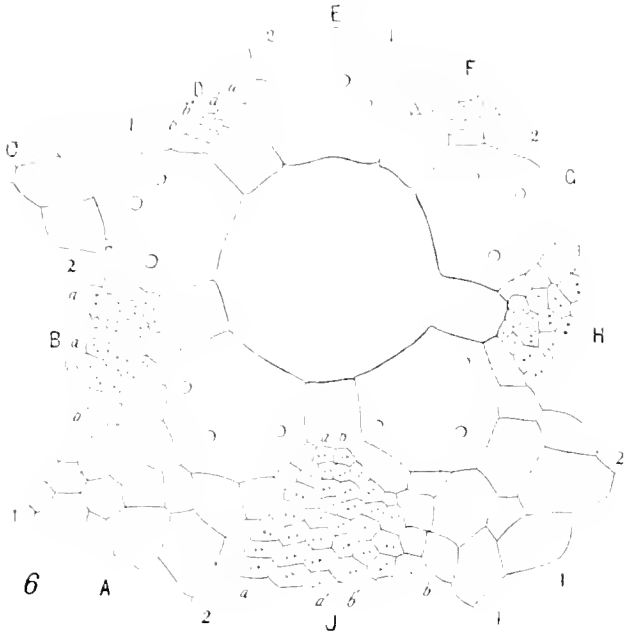
Fig. 10. F. Braun Coll. × 2. Pyramids in place with teeth (p. 379).

Fig. 11. After Jackson and Jaggar, 1896, Plate 5, fig. 20. Mus. Comp. Zool. Coll., 3,005. × 0.9. Specimen with nine columns of plates in two interambulacral areas, the extreme highest number known in the species. Interambulacral plates rhombic dorsally and strung out so that succeeding plates of a given column are separated and not in serial contact as seen in the upper part of figure (p. 377).

Fig. 12. Mus. Comp. Zoöl. Coll., 3,161. × 2.4. Ambulacral plates with tubercles and pore-pairs in peripodia (p. 376).

Fig. 13. After Jackson and Jaggar, 1896, Plate 2, fig. 1. Mus. Comp. Zoöl. Coll., 2,988. × about 5. Spines tapering. Some of the spines show slight constrictions, but these are quite probably accidental, as two other specimens of this species in the Museum of Comparative Zoölogy 2,996 and 3,079, with excellent spines show no evidence of such constrictions (p. 377).

Figs. 2, 7, 8, and 11 drawn by J. H. Emerton; fig. 13 by A. M. Westergren; all others by J. Henry Blake.



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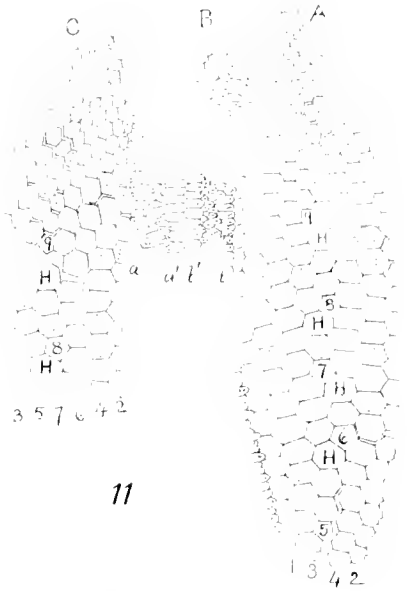

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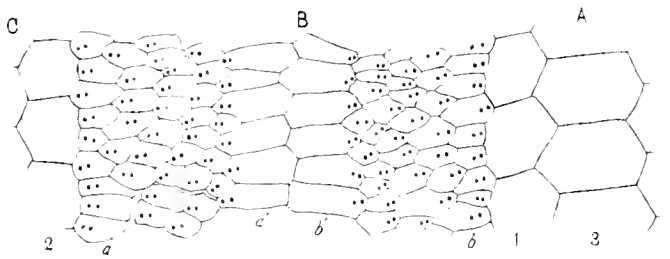

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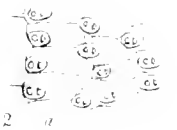

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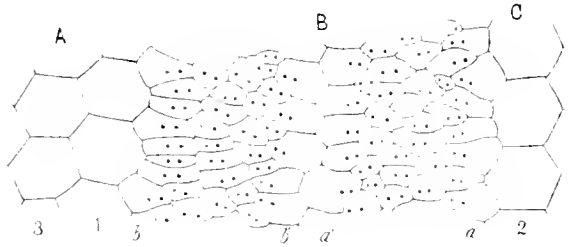

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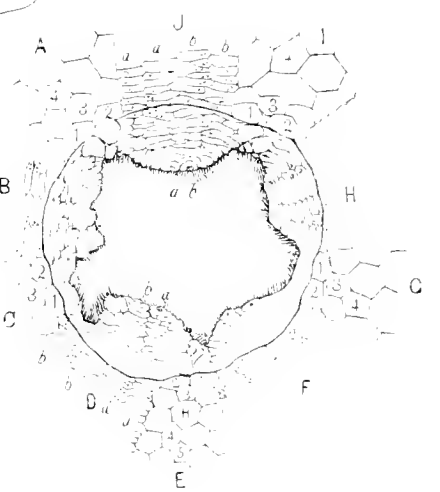

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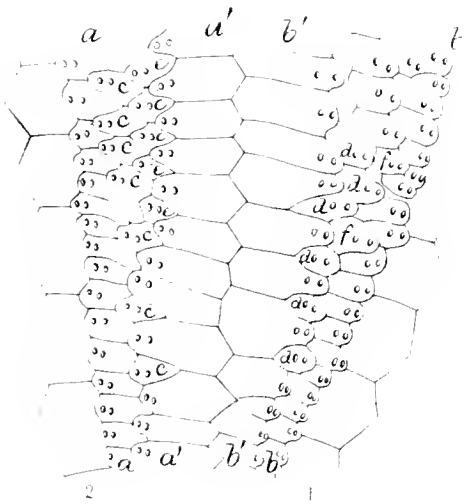

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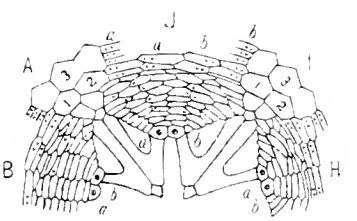

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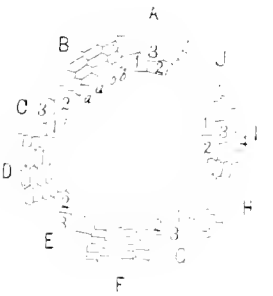

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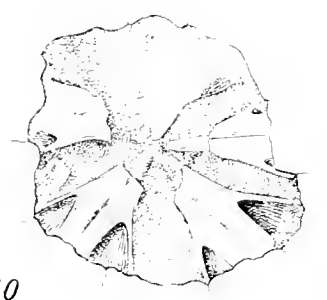

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PLATE 57.

Melonechinus multiporus (Norwood and Owen). Page 375.

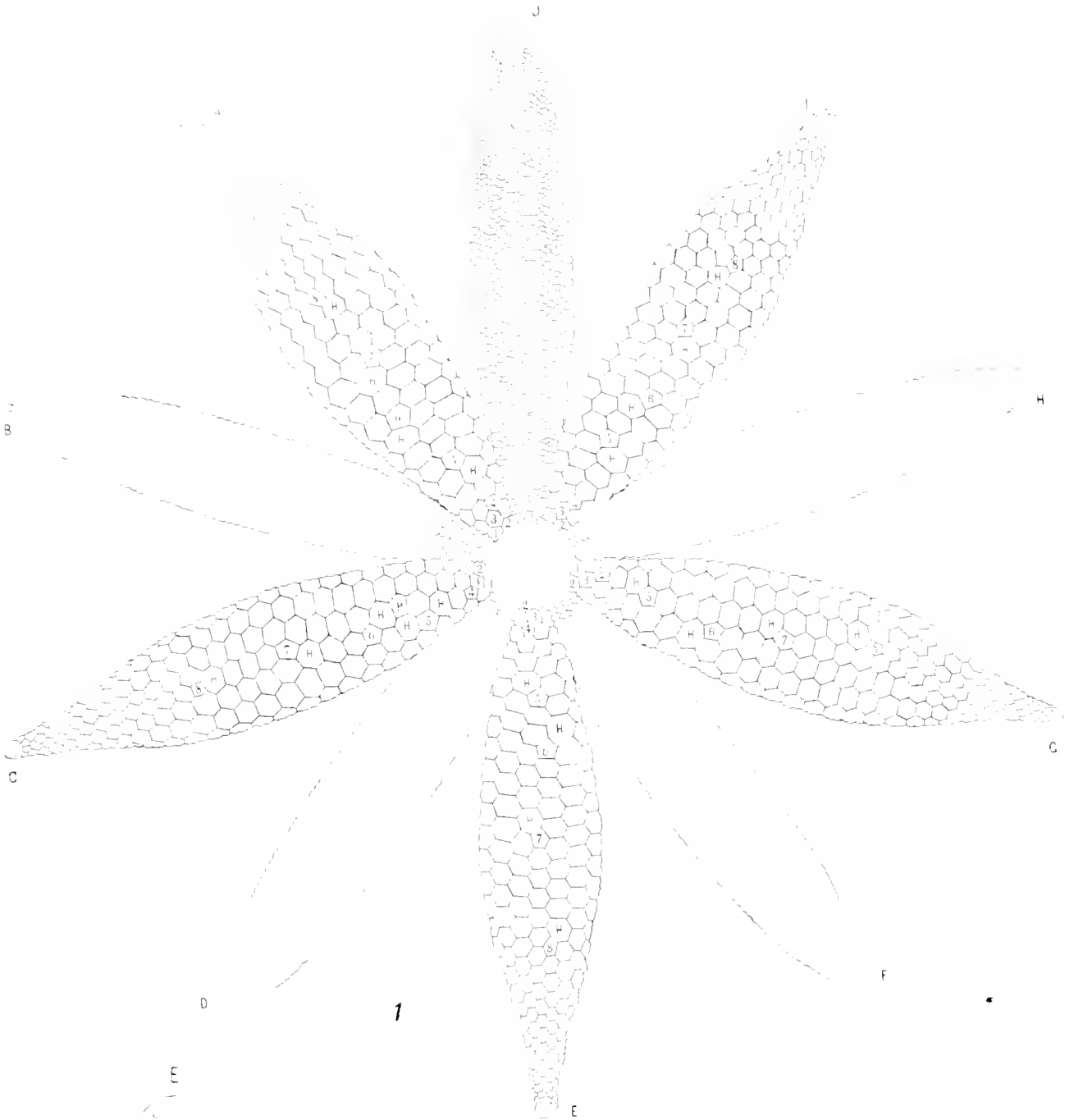
Figs. 1–3. Same specimen as photographs, Plate 55, figs. 1, 2. The most perfectly preserved specimen of a Palaeozoic sea-urchin that I have seen, so that I am able to show it spread out by the Lovén method with every plate in place excepting a few which are restored in the basicoronal row of interambulacral areas A, C, and E, as indicated by dotted lines (pp. 381–384).

Fig. 1. Spread out to show five interambulacra and one ambulacrum complete from the basicoronal row to the apical disc. Natural size. In ambulacrum J, also D, F, and H, there are four plates in a row ventrally. Passing dorsally in J are found in addition dissociated isolated ambulacral plates in the middle of each half-area, then isolated plates become more frequent and are continuous, thus making three columns of plates in a half-area; next more isolated plates appear, making four columns of plates in a half-area; then still more series of isolated plates originate, making five columns in a half-area at the mid-zone, which is the specific character. Above the mid-zone we soon pass dorsally into an area with four plates in a row to a half-area, higher up only three plates in a row, and near the ocular plate only two plates in a row in each half-area, and in actual contact with the ocular there is only a single primary plate in each half-area, a simpler condition than that seen in the youthful plates ventrally (compare text-fig. 237, p. 231). In ambulacrum B there are only two plates ventrally, enlarged in fig. 3; this character of primary plates occurring in the ventral zone is a unique regressive variation for the genus as far as known. The ambulacral areas as in this figure are shown more enlarged in text-fig. 245, p. 382.

In interambulacra I and G there are two plates in the basicoronal row, but the plates of this lowest row are partly or wholly restored in the other three interambulacral areas, as indicated by dotted lines (compare text-fig. 245, p. 382). In all interambulacra the initial plate of column 3 is a hexagonal plate in the second row. In interambulacra A, E, and I the initial plate of column 4 is a pentagon in the third row on the right of the center, but in areas G and C this plate of the column 4 is on the left of the center. In interambulacrum I the initial plate of column 5 is a pentagon in the center in the seventh row, with a heptagonal plate on its right ventral border. In area G, pentagon 5 is in the sixth row with the heptagon on its left ventral border. In area E, pentagon 5 is in the seventh row with the heptagon on its right ventral border. In area C, pentagon 5 is on the left of the center in the sixth row with the heptagon on its right ventral border, and in area A the pentagon 5 is in the center in the sixth row with the heptagon on its right ventral border. In interambulacrum I the initial plate of column 6 is a pentagon on the right of the center in the tenth row with a heptagon on its left ventral border. In area G, pentagon 6 is also on the right of the center in the tenth row, but the heptagon is on its right ventral border. In areas E and A pentagon 6 is on the left of the center in the tenth row with the heptagon on the left ventral border. In area C, pentagon 6 is also on the left of the center, but in the ninth row with the heptagon on its right ventral border. In interambulacrum I the initial plate of column 7 is a pentagon in the center with a heptagon on its right ventral border. The initial pentagon of column 7 is in the center in all other areas with the heptagon on its right ventral border in area E, but on its left ventral border in areas G, C, and A. The seventh column originates in the fourteenth row in areas I and G, in the fifteenth row in area E, and in the thirteenth row in areas C and A. In interambulacrum I, the initial plate of column 8 is a pentagon on the right of the center, with a heptagon on its left ventral border. The initial pentagon of column 8 is on the left of the center in areas G, E, and A, but by rather rare exception in area C the initial plate of column 8 is a tetragonal plate, on the left of the center with two adjacent heptagons to compensate for its two sides wanting. The heptagon next to initial pentagon 8 is on its left ventral border in areas I, E, and G, but on its right ventral border in area A. The eighth column originates in the 18th row in areas I and C, in the 19th row in area G, in the 21st row in area E, and in the 17th row in area A. (Compare text-figs. 25, p. 70; 245 and 246, p. 382.) Dorsally in each area all the columns of interambulacral plates continue to the apical disc, but are strung out dorso-ventrally as is usual in that area (pp. 378, 381–384).

Fig. 2. Dorsal area. × 4. Shows ambulacrum J, with two plates next to the ocular and the number of plates in a row increases passing ventrally. The young interambulacral plates are in contact with the lateral borders of ocular J on either side. Oculars are all imperforate and reach the periproct. Genital G has four pores; all other genitals have three pores each.

Fig. 3. Ventral part of ambulacrum B. × 4. As a radial regressive variation, this area has a few primary plates extending across the half-area. Above these primary plates are demi- and occluded plates, which is the usual character of the ventral ambulacral plates in the genus. Primary plates are characteristic of Palaeechinus at the mid-zone, and also are characteristic as a ventral developing stage in Lovenechinus (Plate 42, fig. 1) and Oligoporus. For such primary plates to occur ventrally in Melonechinus is a case of extreme radial regressive variation and is a unique variant for the genus (pp. 19, 228, 360, 381).



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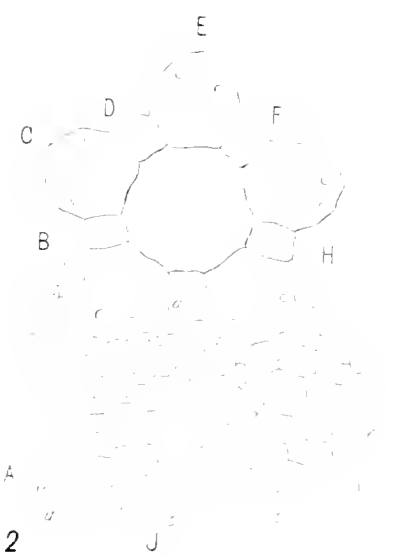

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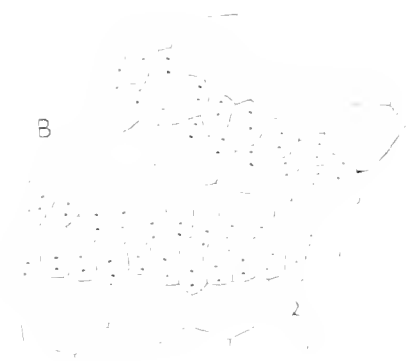

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PLATE 58.

Melonechinus keepingi sp. nov. Page 384.

Fig. 1. Lower Carboniferous Limestone, Gledstone, Gisburn, Yorkshire, England. Museum of Practical Geology, London, 6,583, holotype. Natural size. There are twelve columns of plates in an ambulacral area near the mid-zone. Just above the letter J are seen the two median columns of occluded plates, which are relatively narrow for the genus and not built up in melon-like ribs (pp. 359, 384). There are plates of ambulacrum B in place dorsally which serve to fix the limits of the interambulacrum. The interambulacrum has six columns of plates, but columns 1 and 2 drop out dorsally indicating senescence; tubercles and peripodia are well preserved. A highly specialized species. Drawings, Plate 59, figs. 1–3.

Melonechinus giganteus (Jackson). Page 389.

Fig. 2. Mississippi Group, Lower Carboniferous, Cumberland Gap, Tennessee. U. S. Nat. Mus. Coll., 39,909. Natural size. (This is the holotype of *Melonites granulatus* Troost, which with present evidence is not distinguishable from *giganteus*, and is here considered a synonym, p. 392). There are twelve columns of plates in an ambulacral area; the interambulacrum is incomplete, so that the number of columns is unknown, but a left adradial and five median columns are in place (p. 392). Drawing, Plate 59, fig. 4.

Melonechinus etheridgii (Keeping). Page 385.

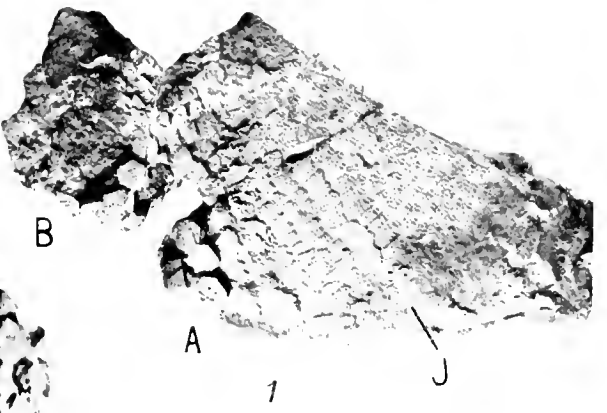
Fig. 3. Lower Carboniferous Limestone, Clitheroe, Lancashire. (In regard to the locality of this specimen see p. 387.) Museum of Practical Geology Coll., London, 6,578, paratype. Natural size. There are six columns of plates in the left half-ambulacrum and also some plates of the right half-ambulacrum. Above the letter J are seen the two median columns of occluded plates which are relatively narrow for the genus and as in *M. keepingi* are not built up in melon-like ribs as they are in American species of the genus (pp. 359, 386). Six of the probably seven columns of plates are in place in the adjacent interambulacral area. Spines, tubercles, and peripodia are preserved in parts. Drawing, Plate 59, fig. 5.

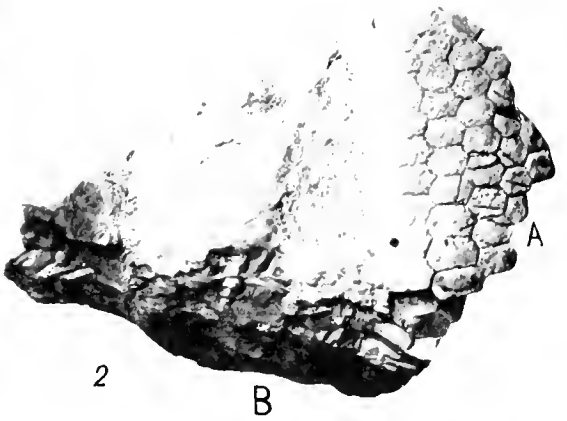
Fig. 4. Same horizon, Clitheroe, Lancashire. (In regard to the locality of this specimen see p. 387.) Museum of Practical Geology Coll., 6,577, holotype. Natural size. Part of Keeping's original slab, composed of more or less dissociated ambulacral areas and interambulacral plates. Drawing, Plate 59, fig. 6.

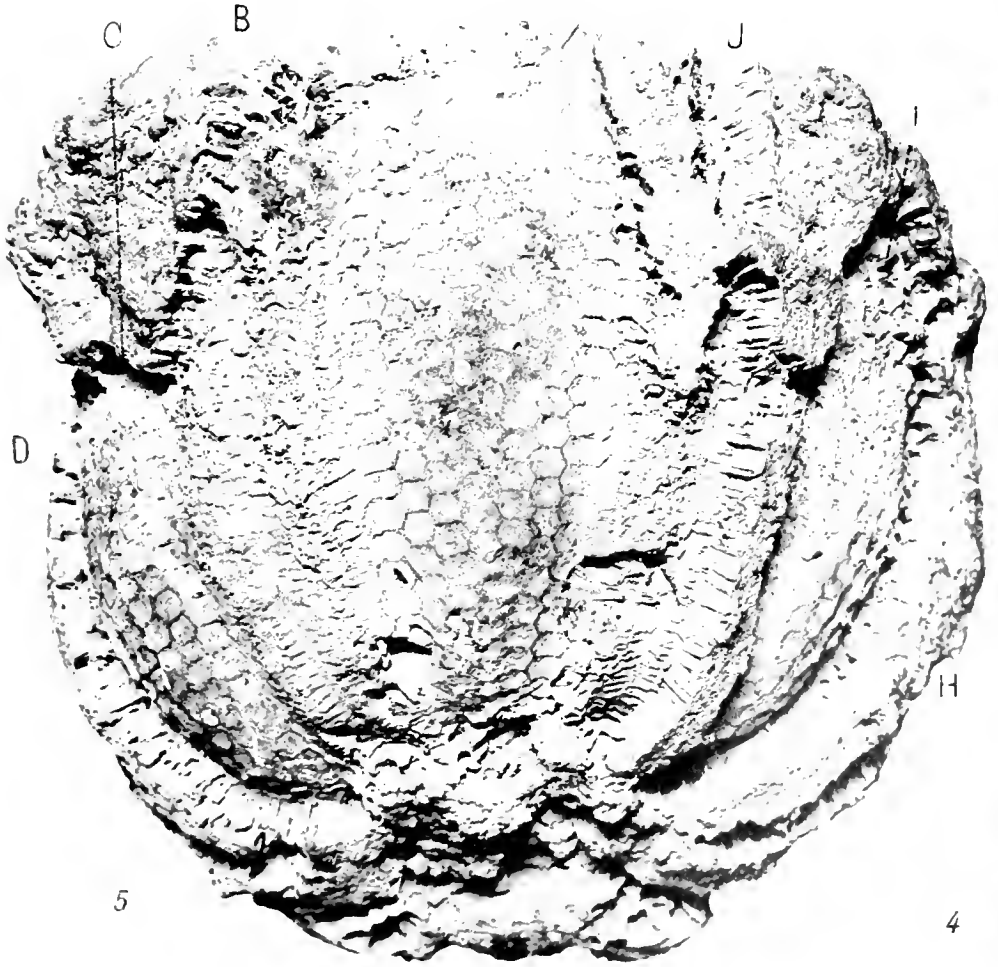
Melonechinus vanderbilti sp. nov. Page 388.

Fig. 5. Lower Carboniferous. Locality unknown, but probably from Tennessee. Vanderbilt University Coll., 220, holotype. Natural size. The specimen is a siliceous internal mold, or in part a siliceous pseudomorph of the plates. There are twelve columns of plates in an ambulacral area at the mid-zone and nine columns of plates in each of the five interambulacral areas. The numbers in white indicate the points of introduction of the several interambulacral columns. Drawings, Plate 61, figs. 1–4.

Figs. 1, 3, and 4 from photographs taken by J. W. Tutcher; fig. 2 by H. W. Tupper; fig. 5 by F. A. Saunderson.







HELIOTYPE CO. BOSTON

PLATE 59.

Melonechinus keepingi sp. nov. Page 384.

Figs. 1–3. Same specimen as photograph, Plate 58, fig. 1. Holotype.

Fig. 1. Upper part of a test. × 2.7. Ambulacrum with twelve columns of plates at the mid-zone; there are only two plates in the area dorsally, increasing passing ventrally to the full number of twelve columns at the mid-zone. (Compare text-fig. 237, p. 231.) Six columns of plates in the interambulacral area near the mid-zone, partly restored as indicated by dotted lines. The adambulacral columns 1 and 2 drop out dorsally, above which 3 and 4 become the adradial columns, a senescent character indicating an old-age individual.

Fig. 2. Ambulacral plates, showing pore-pairs and tubercles. × 2.8.

Fig. 3. Interambulacral plates, showing tubercles. × 2.7.

Melonechinus giganteus (Jackson). Page 389.

Fig. 4. Same specimen as photograph, Plate 58, fig. 2, (holotype of *M. granulatus* Troost, here considered a synonym). × 1.3. Twelve columns of plates in an ambulacral area and six of the columns of interambulacrum A are in place; the rest are wanting on the right, but how many columns are absent is unknown (p. 392).

Melonechinus etheridgii (Keeping). Page 385.

Fig. 5. Same specimen as photograph, Plate 58, fig. 3. Paratype. × 0.9. There are six columns of plates in the left half-ambulacrum, with also a few plates of the right half-ambulacrum. There are six columns of interambulacral plates in place and a seventh or adambulacral column is restored on the left of the figure as indicated by dotted lines (p. 387).

Fig. 6. Same specimen as photograph, Plate 58, fig. 4. Holotype. × 1.4. Part of a half-ambulacrum. The plates of the median occluded column *b* are only slightly wider than the plates of isolated columns (p. 386).

Fig. 7. Lower Carboniferous Limestone, Frome, Somerset, England. British Mus. Coll., E 1,400. Ambulacral plates with pore-pairs and tubercles (p. 388). × 2.7.

Fig. 8. Lower Carboniferous, Coplaw, Clitheroe, Lancashire. Museum of Practical Geology Coll., 16,303. × 2.8. Ambulacral plates seen from the interior, face of plates rounded inwardly, pores about in the middle of the plates instead of toward the next interambulacrum as on the exterior (p. 387).

Figs. 9–11. Lower Carboniferous Limestone, Frome, Somerset. British Mus. Coll, E 1,400. × 2.7.

Fig. 9. Interambulacral plate with tubercles and spines (p. 388).

Fig. 10. Adradial plate with beveled adradial suture face (p. 388).

Fig. 11. Adradial plate with facets for articulation with the ambulacral plates on the adradial face (p. 388).

Melonechinus giganteus (Jackson). Page 389.

Figs. 12–15. Same specimen as photograph, Plate 60, fig. 3. Holotype (after Jackson, 1896, Plate 5, figs. 21–24).

Fig. 12. Ambulacral detail from the right lower side of ambulacrum B (see photographic figure, Plate 60, fig. 3). × 2. Only five columns of plates in a half-area are seen in this figure whereas six occur in a half-area at the ambitus, as seen in Plate 61, fig. 8. (Compare figs. 12 and 13 with text-fig. 237, p. 231.)

Fig. 13. Ventral portion of the test. × 2. Ambulacra have four columns of plates ventrally in each area; in the interambulacra the basicoronal row is wanting, but is restored in area A as indicated by dotted lines. There are three plates in the second row, four plates in the third row, and five plates in the fifth row.

Fig. 14. Interambulacrum A. Natural size. The basicoronal row is wanting. In the first row preserved there are three plates, in the next row four plates; the columns 5, 6, and 7 originate very early, showing an accelerated development. Column 8 originates early; column 9 originates with a tetragonal plate against which are two heptagons, H′, H″, to compensate for the two sides wanting. Above the tetragon is one row of eight plates, then column 9 begins again with a pentagonal plate, with a heptagon, H, on its right ventral border. This is a very exceptional anomaly (compare Plate 50, figs. 2, 3). Column 10 originates just below the mid-zone, and column 11 in the dorsal third of the area; column 11 drops out dorsally toward the apical disc, a senescent character (p. 391).

Fig. 15. A single interambulacral plate with tubercles. × 4.

Figs. 1–3, 5–11 drawn by A. T. Hollick; fig. 4 by J. Henry Blake; figs. 12–15 by J. H. Emerton.

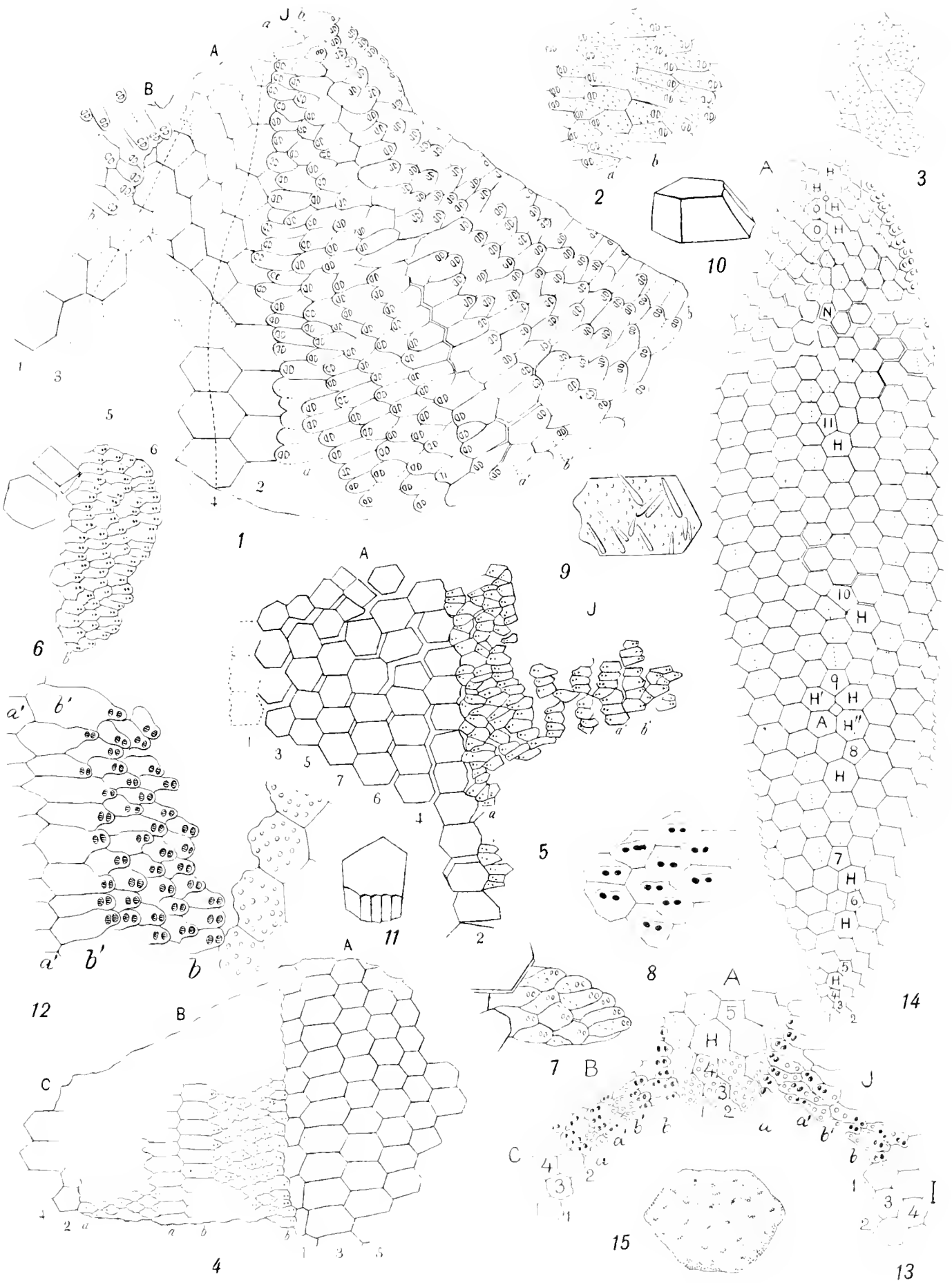


PLATE 60.

Melonechinus multiporus (Norwood and Owen). Page 375.

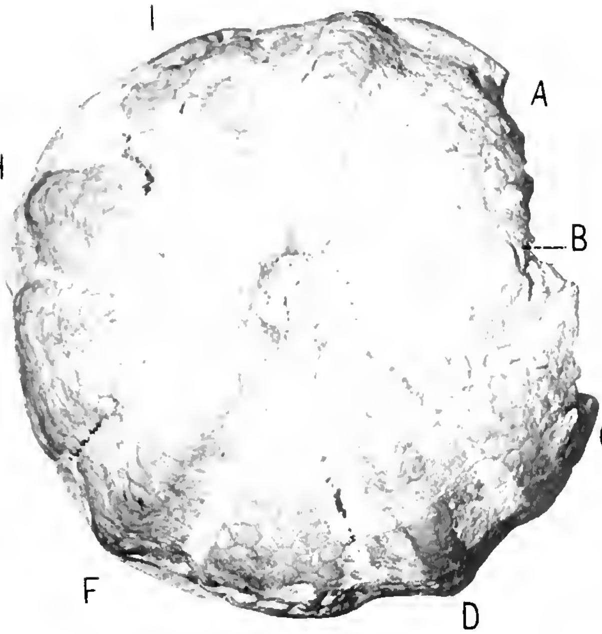
Fig. 1. St. Louis Group, Lower Carboniferous, St. Louis, Missouri. F. Springer Coll., 8,023 (from G. Hambach Coll.). Natural size. A quite typical adult specimen; melon-like ribs are rounded, moderately elevated; there are eight columns of plates in each interambulacral area; interambulacral plates are rhombic dorsally; ocular and genital plates are all in place. Genital G has three or perhaps four pores, all other genitals have three pores each. The apical disc measures proportionately 16% of the diameter of the test (pp. 376, 379, 384).

Fig. 2. Same horizon and locality. F. Springer Coll., 8,108 (from G. Hambach Coll., K 8, the original of Miss Klem's, 1901, Plate 4, figs. 8a–8d). Natural size. Similar specimen to the above, but with nine columns of plates in each interambulacral area. Oculars are all insert. Genital E has three pores, genitals A and C apparently have four pores each, genital I is doubtful, and genital G has only two pores, a very unusual number. No pores seem to have been obliterated in this plate. The diameter of the apical disc measures proportionately about 16% of the diameter of the test (pp. 379, 384).

Melonechinus giganteus (Jackson). Page 389.

Fig. 3. Lower Carboniferous, Bowling Green, Kentucky. Mus. Comp. Zoöl. Coll., 2,989, holotype. Natural size. Ventral view. The specimen is a siliceous pseudomorph in fine condition of preservation and represents probably the largest known Palaeozoic echinoid. Melon-like ribs are strongly and sharply elevated. There are twelve columns of plates at the mid-zone in the ambulacral areas and eleven columns of plates above the mid-zone in each interambulacral area. The introduction of the columns of interambulacral plates can be plainly followed in several interambulacral areas, and is especially clear in area A. As seen imperfectly on the dorsal side of this specimen the apical disc measures about 15–16% of the diameter of the test. Drawings, Plate 59, figs. 12–15.

Figs. 1, 2, photographs by F. A. Saunderson; fig. 3 by C. H. Currier.



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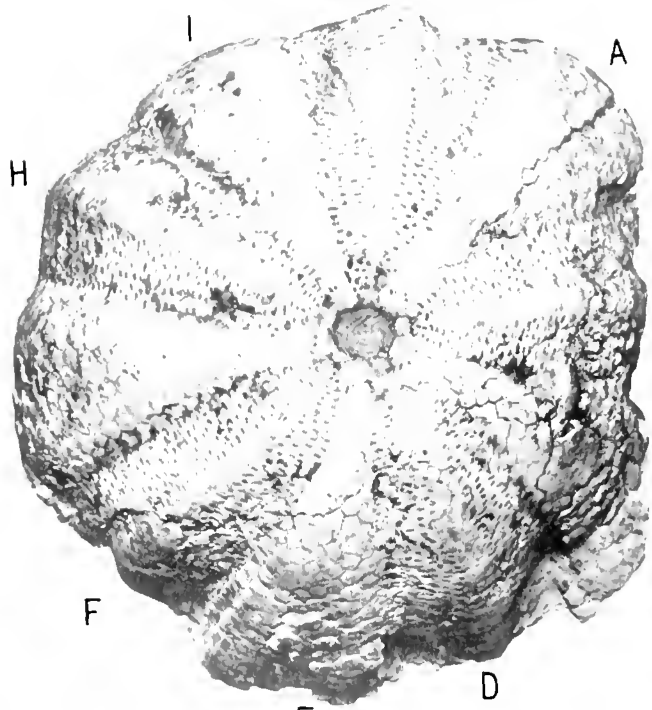

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H. CURRIER F. A. SAUNDERSON PHOTO

HELIOTYPE CO. BOSTON

PLATE 61.

Melonechinus vanderbilti sp. nov. Page 388.

Figs. 1–4. Same specimen as photograph, Plate 58, fig. 5. Holotype.

Fig. 1. Section dorsal to the mid-zone. × 1.9. A half-ambulacrum in surface view, and an interambulacrum drawn from the internal mold of the base of the plates. Six columns of plates in a half-area of an ambulacrum, and nine columns of plates in an interambulacral area. Ambulacral plates have tubercles and peripodia.

Fig. 2. Interambulacrum A. × 0.9. Drawn largely from an internal mold of the plates, but a few plates are in place as indicated by those having tubercles, partly restored ventrally and dorsally as indicated by dotted lines. There are three plates in the second row, four plates in the third row, column 5 originating in the seventh row. An exceptional pentagon, P, in the fifth row of column 5 has a compensating heptagonal plate, H, on its right side. Column 6 originates on the left of the center in the tenth row, column 7 in the 14th row, column 8 in the 20th row, and column 9 in the 29th row. Curiously, in both columns 8 and 9, there is an exceptional pentagon, P, with adjacent heptagons similar to that seen in column 5. Dorsally columns 1 and 2 drop out at the points X and columns 5 and 8 at the points P′, P″, so that above this zone there are only five columns of plates in the area, indicating a senescent individual.

Fig. 3. Surface detail. × 2.8. Pore-pairs are in peripodia and lie toward the next adjacent interambulacrum in each plate; tubercles are represented on interambulacral plates.

Fig. 4. Inner detail of an ambulacrum drawn from an internal mold. × 2.8. Pore-pairs are in the middle of the plates of the inner columns of isolated plates, or toward the median line of the half-area in the lateral ambulacral column of demi-plates. Ambulacral plates are fan-shaped opposite the horizontal interambulacral sutures.

Melonechinus giganteus (Jackson). Page 389.

Figs. 5–9. St. Louis Group, Lower Carboniferous, Clarksville, Tennessee. U. S. Nat. Mus. Coll., 42,340.

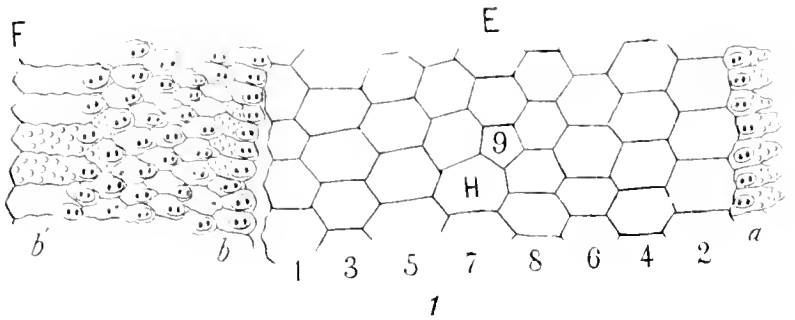
Fig. 5. Detail of ambulacrum from the exterior. × 2.8. Pore-pairs are in peripodia toward the adjacent interambulacrum in each plate, tubercles on interambulacral plates.

Fig. 6. Same individual plates seen from the interior. × 2.7. Pore-pairs of the median isolated columns are in the middle of each plate, but pore-pairs of the column of demi-plates bordering on the interambulacrum are in the inner border of each plate. Adambulacral plates are rounded on the adradial suture.

Fig. 7. Profile view of plates shown in figs. 5 and 6. × 2.7. The plates marked X and XX locate the individual plates of the several figures (pp. 360–390).

Fig. 8. Segment across a half-ambulacrum and completely across an interambulacrum, to show surface character. × 2.7. There are six columns of plates in the right half-ambulacrum and eleven columns of interambulacral plates, the eleventh appearing in this view, which is about on the plane of the mid-zone. Peripodia are shown in ambulacral plates and tubercles on the same, and on a few interambulacral plates. (Compare text-fig. 237, p. 231.)

Fig. 9. Segment showing structure viewed from the interior. × 2.7. Pore-pairs are in the middle of all isolated ambulacral plates; but in the plates of the median (occluded) and lateral (demi-) columns the pore-pairs in each plate are toward the middle of the half-area. Ambulacral plates are fan-shaped opposite the horizontal interambulacral sutures (p. 60). (Compare Plate 56, fig. 5.)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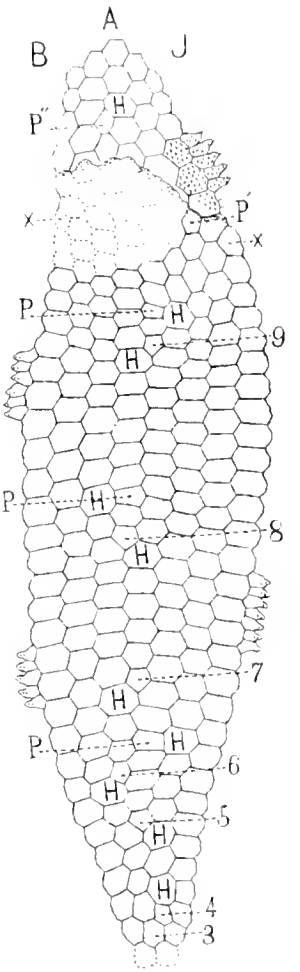
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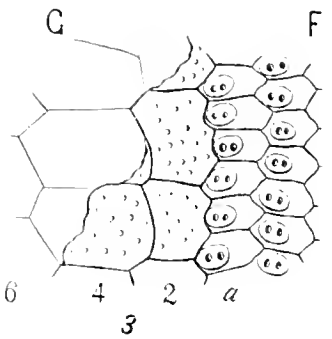
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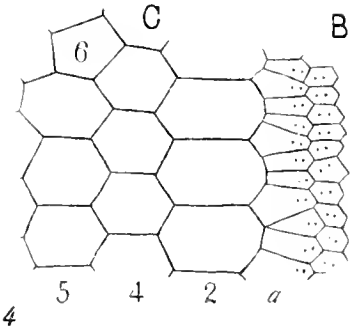
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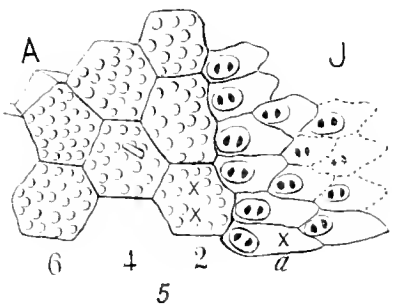
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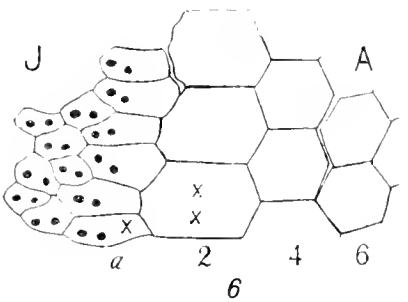
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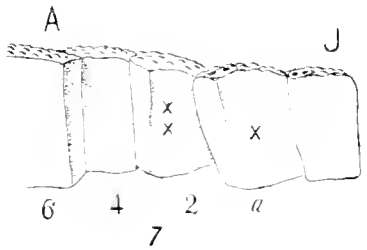
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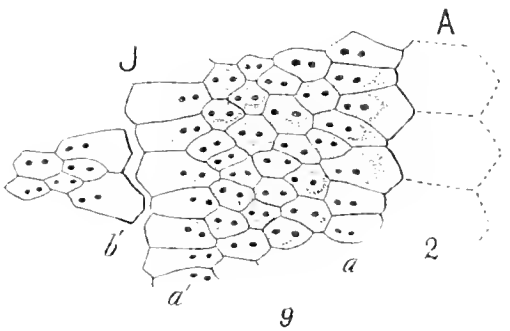
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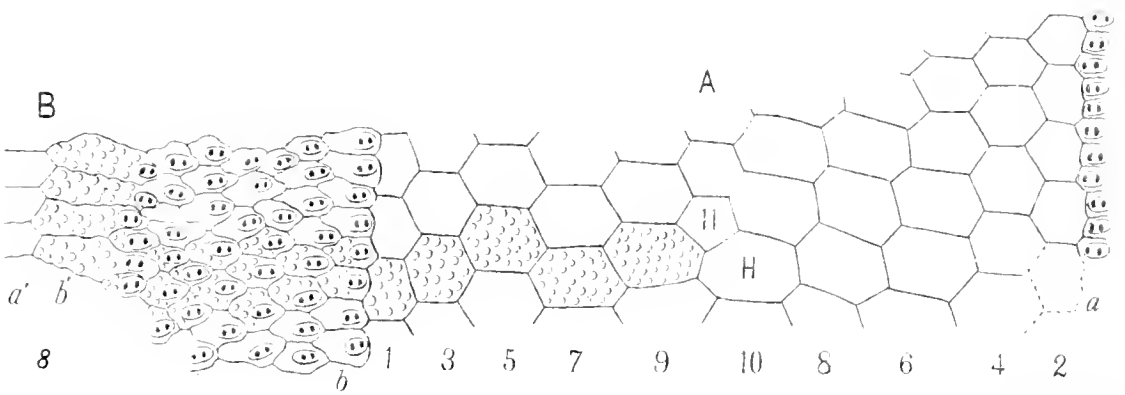
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PLATE 62.

Lepidechinus iowensis sp. nov. Page 397.

Fig. 1. Upper Burlington Limestone, Lower Carboniferous, Burlington, Iowa. F. Springer Coll., 8,010, holotype. Natural size. Five columns of moderately imbricating plates in two interambulacral areas and two columns of low plates in each ambulacral area. The ambulacral plates are seen best in area J. Drawings, Plate 63, figs. 3 and 4.

Lepidechinus tessellatus sp. nov. Page 397.

Fig. 2. Upper Burlington Limestone, Lower Carboniferous, Burlington, Iowa. Mus. Comp. Zoöl. Coll., 3,053, holotype. Natural size. Six columns of rounded hexagonal, moderately imbricating plates in each interambulacral area and two columns of low plates in each ambulacrum. Drawings, Plate 63, figs. 5 and 6.

Fig. 3. Same horizon and locality. Mus. Comp. Zool. Coll., 3,054, paratype. × 2. Specimen seen from the interior; ambulacra are wider than on the exterior, six columns of plates in each interambulacral area, and the plates are more sharply hexagonal than on the exterior. Ocular fail to reach the periproct or are exsert, each bearing a pore, and each ocular plate adorally covers an ambulacrum and laterally an interambulacrum in part on each side. Genitals with a single pore in the middle of the plates, a character seen in no other Palaeozoic type (pp. 171, 221). Drawings, Plate 63, figs. 7, 8.

Fig. 4. Same horizon and locality. F. Springer Coll., 8,011, paratype. Natural size. Six columns of moderately imbricating plates in the interambulacral area and two columns of low plates in each ambulacral area. Drawings, Plate 63, figs. 9–11.

Lepidechinus imbricatus Hall. Page 399.

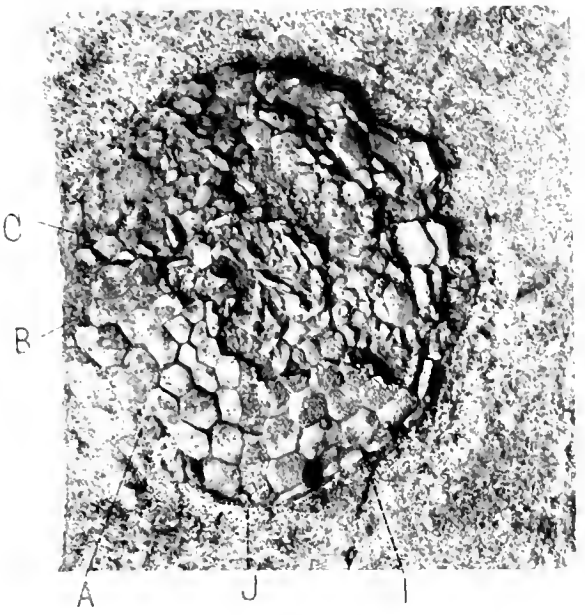
Fig. 5. Burlington Limestone, Lower Carboniferous, Burlington, Iowa. Mus. Comp. Zoöl. Coll., 3,055, holotype. × 2. In each ambulacral area there are two columns of low plates imbricating strongly adorally. In each of the interambulacral areas A and I there are eight columns of plates imbricating strongly aborally and from the center laterally. Drawing, Plate 64, fig. 1.

Perischodomus biserialis M'Coy. Page 401.

Fig. 6. Lower Carboniferous, Ireland, probably from Hook Head. Trinity College Coll., Dublin. Natural size. Internal view of the ventral area. Ambulacral plates are wide and imbricate aborally and bevel over the interambulacrals laterally. Interambulacral plates imbricate adorally and toward the center. (All this direction of beveling is just the reverse of what is seen on the exterior because it is an internal view. Compare text-figs. 32–34, p. 75.) The primordial interambulacral plates are in the basicoronal row; there are two plates in the second row and three plates in the third row, as seen best in areas A and G. The fourth and fifth columns originate in succeeding rows. In area J a few ambulacral plates of the peristome are seen extending beyond the primordial interambulacral plate of area A, compare Plate 23, fig. 1 (p. 404). Drawing, Plate 64, fig. 2.

Fig. 7. Same horizon and locality. Trinity College Coll., Dublin. Natural size. External view of the dorsal side. Two columns of low narrow plates in each ambulacral area, imbricating adorally and beveling under the adambulacrals. Five columns of plates in each interambulacral area near the mid-zone, the plates imbricating adorally and from the center laterally and over the ambulacrals. Two of the median columns drop out, passing dorsally in each area. Eccentric primary tubercles are seen on adradial and some other interambulacral plates (p. 404). Drawings, Plate 64, figs. 3–6.

Figs. 1 and 4 from photographs by F. A. Saunderson; figs. 2, 3, and 5 by H. W. Tupper; figs. 6 and 7 from photographs taken by A. C. Bridle in Dublin



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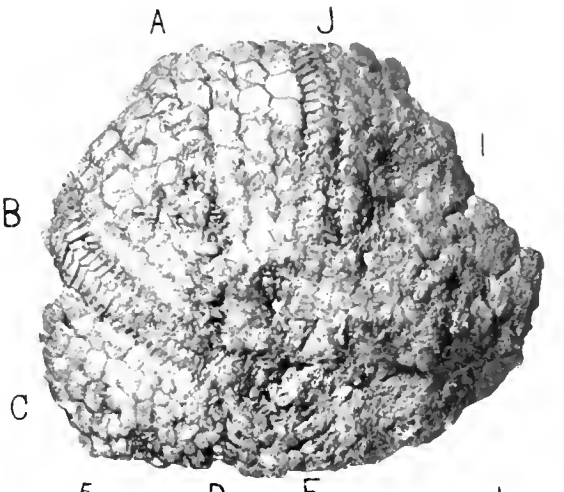

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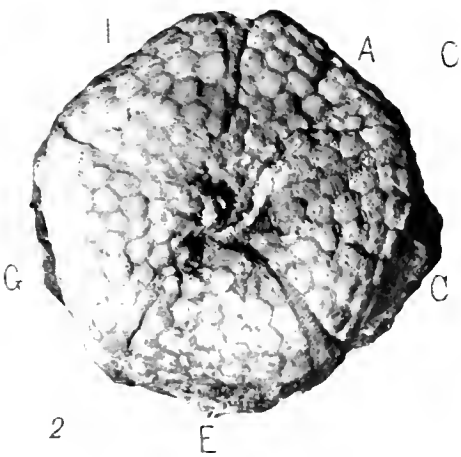

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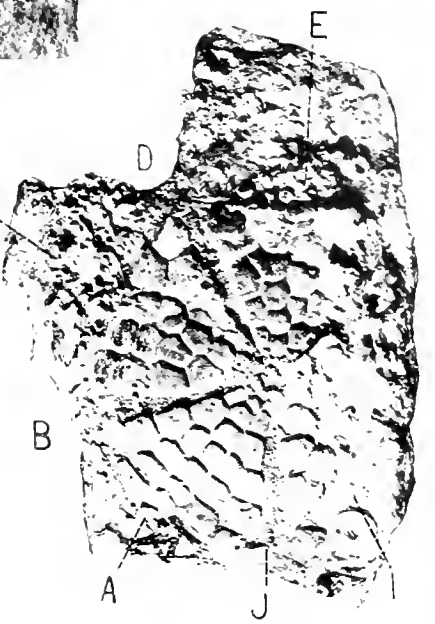

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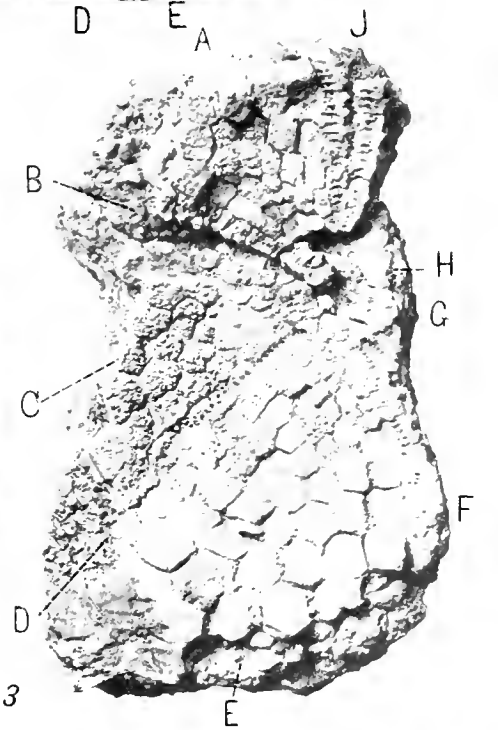

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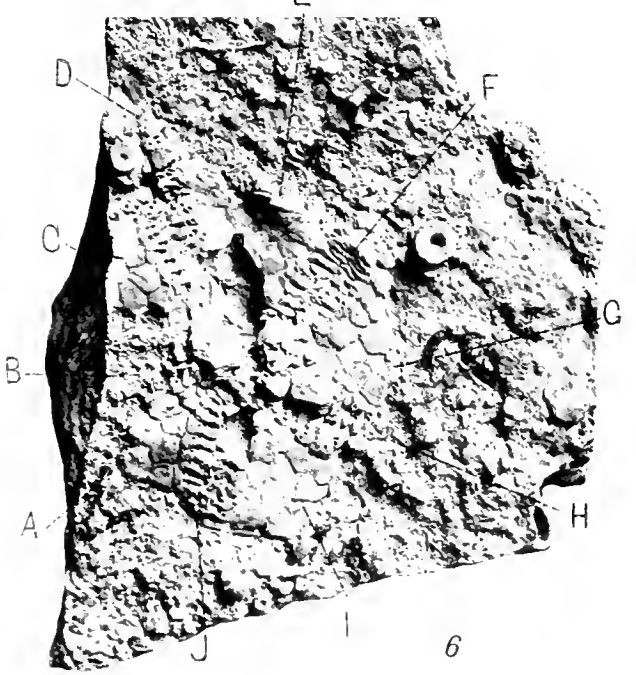

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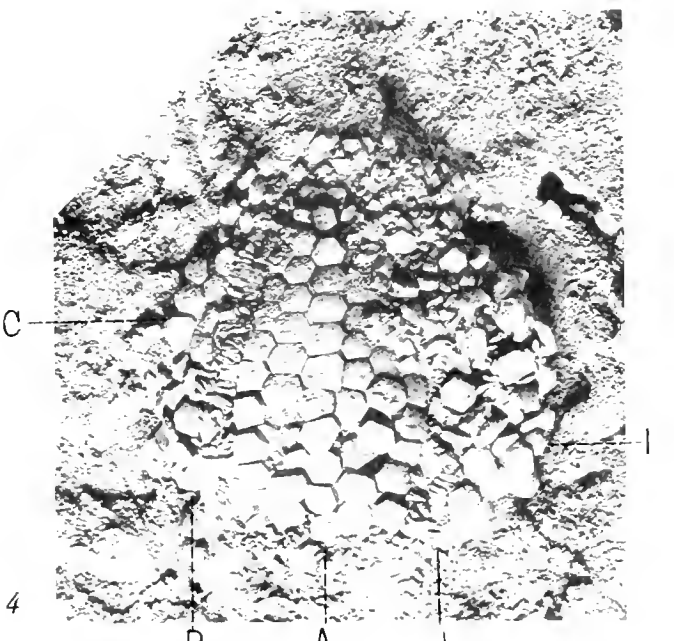

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PLATE 63.

Lepidechinus irregularis (Keeping). Page 396.

Figs. 1, 2. Lower Carboniferous Limestone, Hook Head, County Wexford, Ireland (after Keeping, 1876, Plate 3, figs. 6 and 7). Holotype in Sedgwick Museum, Cambridge, England, no. 12.

Fig. 1. A small species with four or five columns of moderately imbricate plates in an interambulacral area; ambulacra narrow. × 0.9.

Fig. 2. Enlargement of an ambulacrum and interambulacrum. Ambulacral plates are low and narrow; pore-pairs uniserial; interambulacrum with four columns and a trace of a fifth column as represented by one plate dorsally; plates are rounded hexagonal, imbricating moderately dorsally and from the center laterally.

Lepidechinus iowensis sp. nov. Page 397.

Fig. 3. Same specimen as photograph, Plate 62, fig. 1. Holotype. × 1.8. Ambulacral plates are low and narrow, with two columns in each area; pore-pairs uniserial. Interambulacra in each area with five columns of rounded hexagonal plates imbricating moderately dorsally and from the center laterally and over the ambulacra. Tubercles are all secondaries, uniform in size. A dorsal view of a lantern in place shows pyramids, braces, and teeth, which last are strongly inclined, indicating a flaring lantern as in Archaeocidaris.

Fig. 4. The same. × 3.5. Section looking ventrally to show the beveling of ambulacral and interambulacral plates, the latter shaded for contrast.

Lepidechinus tessellatus sp. nov. Page 397.

Fig. 5. Same specimen as photograph, Plate 62, fig. 2. Holotype. × 1.8. Two columns of low plates in each ambulacral area, imbricating moderately ventrally; six columns of rounded hexagonal median or pentagonal adradial plates in each interambulacral area. Interambulacral plates imbricating moderately dorsally and from the center laterally and over the ambulacrals.

Fig. 6. Same specimen. × 3.4. Ambulacral detail enlarged, from the area marked X in fig. 5.

Fig. 7. Same specimen as photograph, Plate 62, fig. 3. Paratype. × 1.7. Seen from the interior. The ambulacra are wider than on the exterior. Six columns of plates in each interambulacral area and the plates are more sharply hexagonal than on the exterior. Oculars each have one pore, and are exsert, an unusual Palaeozoic character (pp. 89, 221); each ocular plate adorally covers an ambulacrum and laterally in part an interambulacrum on either side (p. 52). Each genital plate has a single pore in the middle of the plate, a feature which I have seen in no other Palaeozoic type (pp. 171, 221).

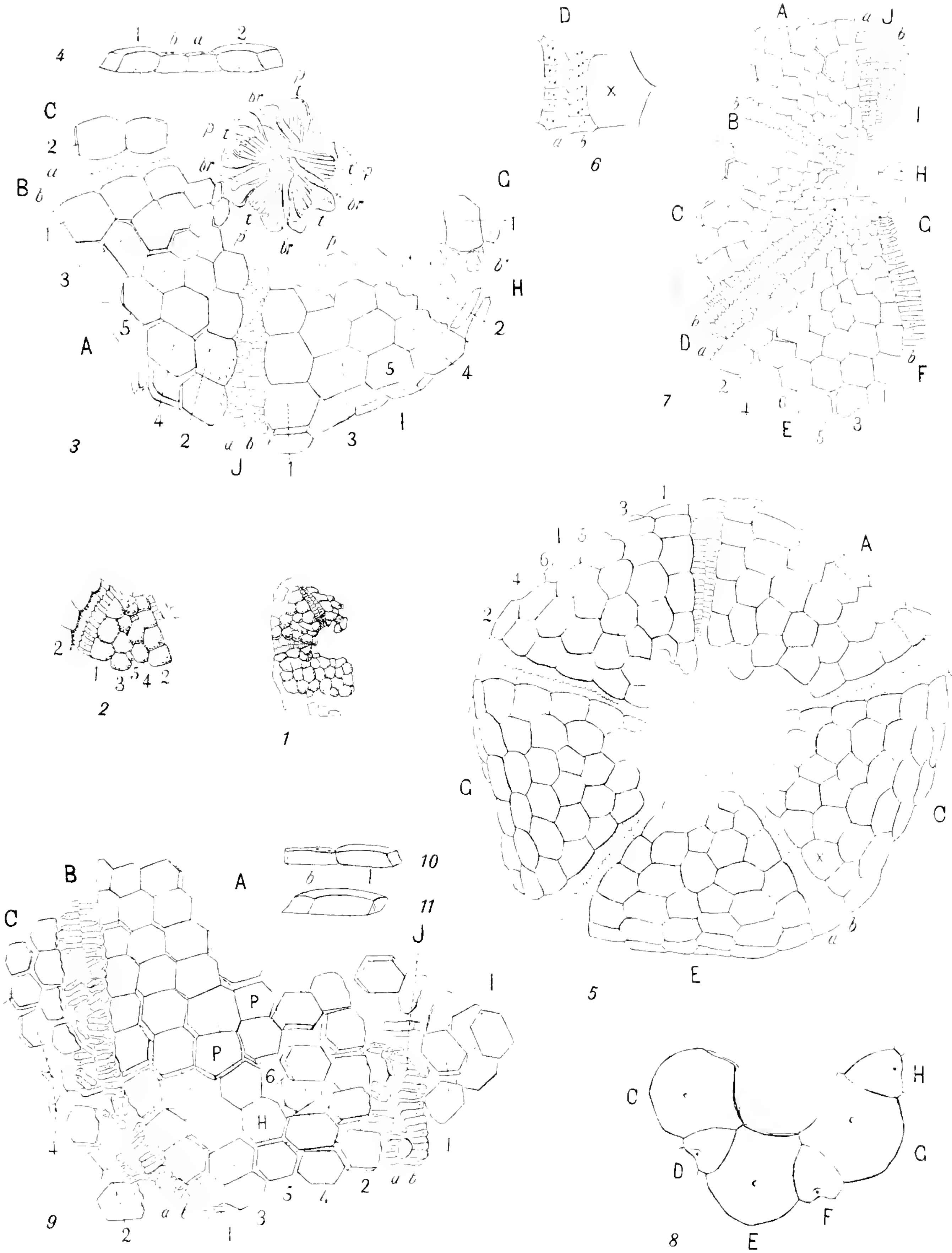
Fig. 8. Same specimen. Ocular and genital plates more enlarged. × 7.

Fig. 9. Same specimen as photograph, Plate 62, fig. 4. Paratype. × 1.8. Six columns of moderately imbricating plates in interambulacrum A; tubercles shown in one plate of area C.

Fig. 10. The same specimen, enlarged to show an interambulacral plate beveling over an ambulacral on the adradial suture. The interambulacral plate shaded.

Fig. 11. The same specimen to show the imbricate edges of an interambulacral plate.

Figs. 1 and 2 copied by W. M. Barrows, all others drawn by J. Henry Blake.



Heliotype Co. Boston

PLATE 64.

Lepidechinus imbricatus Hall. Page 399

Fig. 1. Same specimen as photograph, Plate 62, fig. 5. Holotype. × 2.7. Two columns of low plates in each ambulacral area, imbricating strongly ventrally. Eight columns of plates in the interambulacral areas A and I, the plates imbricating strongly dorsally and from the center laterally and over the ambulacra. There is a single plate in the basicoronal row, two plates in the second row, and thence increasing dorsally to the full number of plates and columns at the mid-zone. In area C, the introduction of columns ventrally is clear, but only seven columns can be counted in this area. Probably an eighth column would have appeared aborally in the part which is wanting.

Perischodomus biserialis M'Coy. Page 401.

Fig. 2. Same specimen as photograph, Plate 62, fig. 6. × 1.8. Internal view of the ventral side. Ambulacral plates are broad, imbricating (in this view) dorsally and from the center laterally and over the adradials. Interambulacral plates imbricate ventrally and toward the center of the area as it is an internal view. (Compare text-figs. 32–38, p. 75, for imbrication seen from the exterior and interior.) The primordial interambulacral plates are in the basicoronal row, there are two plates in the second row, three plates in the third row, four plates in the fourth row, and five plates in the fifth row. In area G two interambulacral plates from the dorsal side are in place, seen from the exterior, but flattened down on to the ventral part of the test (compare Plate 74, fig. 2). This figure is in part restored as indicated by dotted lines (p. 404). (Compare text-fig. 30, p. 70.)

Fig. 3. Same specimen as photograph, Plate 62, fig. 7. × 1.9. Ambulacra are narrow, the plates low, the interambulacra near the mid-zone each with five columns of rounded plates which imbricate strongly dorsally and from the center laterally and over the ambulacra. Two of the columns, 3 and 4, drop out, passing dorsally in each area. An eccentric primary tubercle is on each adradial plate; similar tubercles occur on some plates of median interambulacral columns as shown in the photograph, but they were overlooked in making the drawing (p. 404).

Fig. 4. The same from an area near the mid-zone. × 3.6. Some ambulacral plates are pinched off so that they do not reach across the half-area.

Fig. 5. The same. ×. 3.6. Ambulacral plates near the apical disc, all crossing the half-area, pore-pairs uniserial.

Fig 6. The same enlarged. Ambulacral plates near the mid-zone alternately moderately wedge-shaped, strongly beveled under the adradials.

Figs. 7, 8. Lower Carboniferous, Hook Head, County Wexford, Ireland. Sedgwick Museum Coll., Cambridge, England, (after Keeping, 1876, Plate 3, figs. 1 and 1). Cotype.

Fig. 7. × 0.9. Five columns of plates in each of the three most complete interambulacral areas, two areas are imperfect. There are eccentric primary tubercles on adradial plates and also on some of the plates of the median interambulacral columns.

Fig. 8. Apical disc and part of the corona. × 1.8. There are five genital plates and one small ocular in place. Genital plates have numerous pores. The apical disc is small proportionately to the diameter of the test. Eccentric primary tubercles are shown on several interambulacral plates and the same with secondary tubercles on one plate (p. 403).

Fig. 1 drawn from nature; figs. 2–6 from my sketches by J. Henry Blake; figs. 7 and 8 copied by W. M. Barrows.

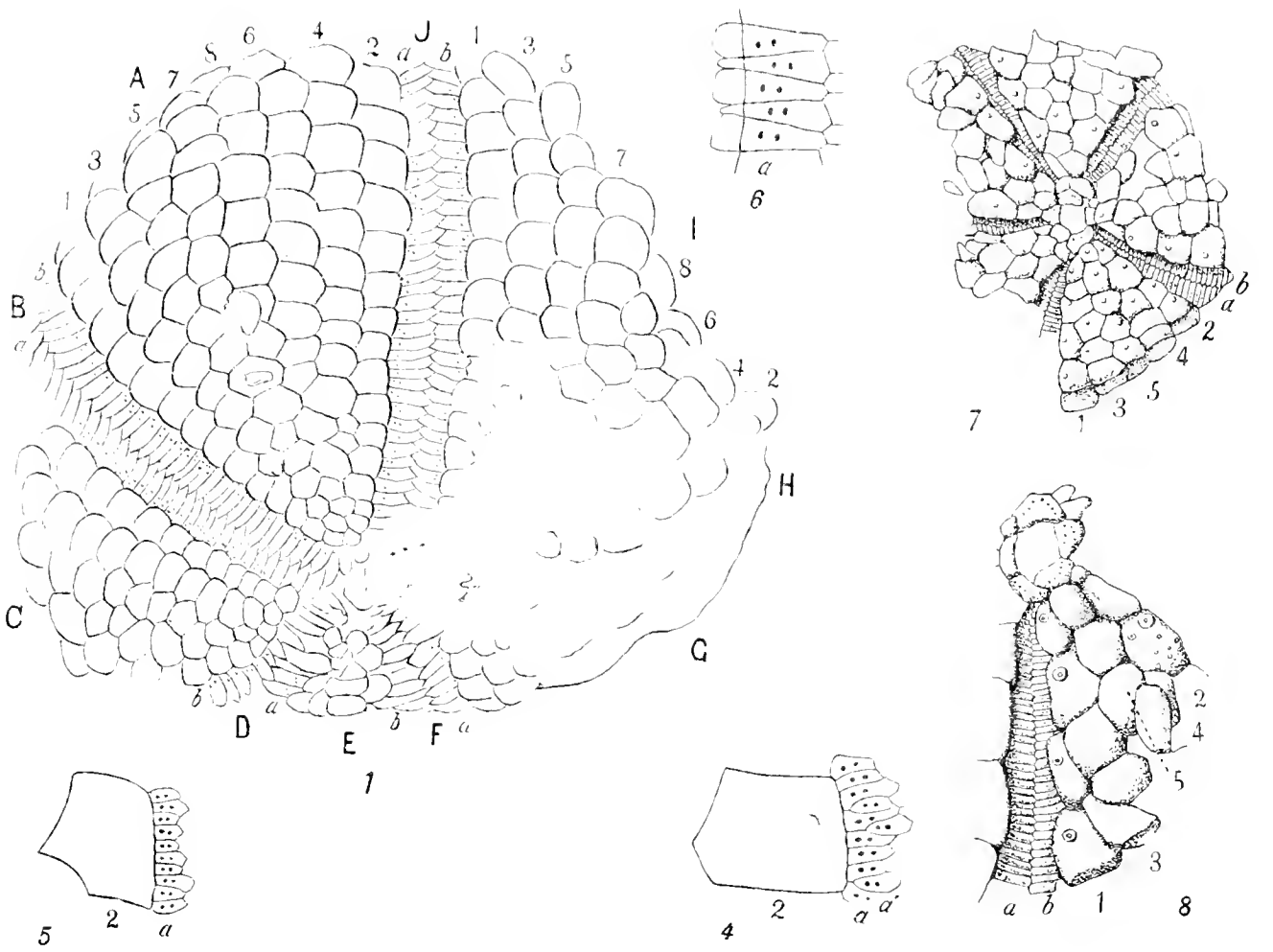

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PLATE 65.

Perischocidaris harteiana (Baily). Page 408.

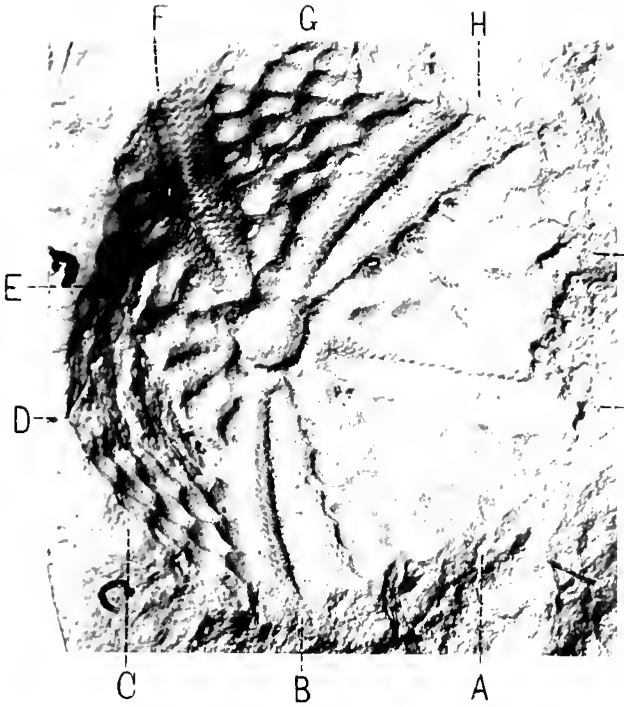
Fig. 1. Lower Carboniferous, west shore of Lough Esk, about six miles from Donegal, Ireland. Trinity College Coll., Dublin. Holotype. Natural size. The specimen is an external sandstone mold. Six columns of plates in each ambulacral area at the mid-zone. Five columns of plates in each interambulacral area near the mid-zone, decreasing in the number of columns dorsally. Genitals and oculars all in place. Drawings, Plate 67, figs. 1–3. On the left in the figure is seen an impression of a second fragmentary specimen.

Fig. 2. Plaster cast of same. Natural size. As this is a replica of the original specimen, the lettering is reversed from that of the sandstone mold (fig. 1).

Proterocidaris giganteus Koninck. Page 410.

Fig. 3. Lower Carboniferous, Dinant, Belgium (after Fraipont, 1904, Plate 4, fig. 2, where it is called *Oligoporus sorcili* sp. nov., here considered a synonym). Natural size. This specimen represents a curious condition of preservation in which most of the test is intact and viewed from the dorsal side, but one interambulacrum I and two adjacent half-ambulacra H and J, are spread out (like peeling down a segment of an orange) and viewed from the interior. Four columns of plates in an ambulacral area; a half-area with two columns of plates is seen from the interior in area J. Eleven columns of interambulacral plates are seen at the mid-zone as viewed from the interior in interambulacrum I; but on the right-hand side of the area a twelfth column appears a little dorsal to the mid-zone. In area I, which is seen from the interior, the plates imbricate adorally and toward the center, largely covering the central column. In other areas seen from the exterior, the interambulacral plates imbricate aborally, and from the center laterally. Plates with tubercles and spines. (In the figure the two letters A in white, are from Fraipont's original photograph and signify ambulacral areas.) Drawings, Plate 67, figs. 6 and 7.

Figs. 1 and 2 from photographs taken by A. C. Bridle in Dublin; fig. 3 copied by F. A. Saunderson.



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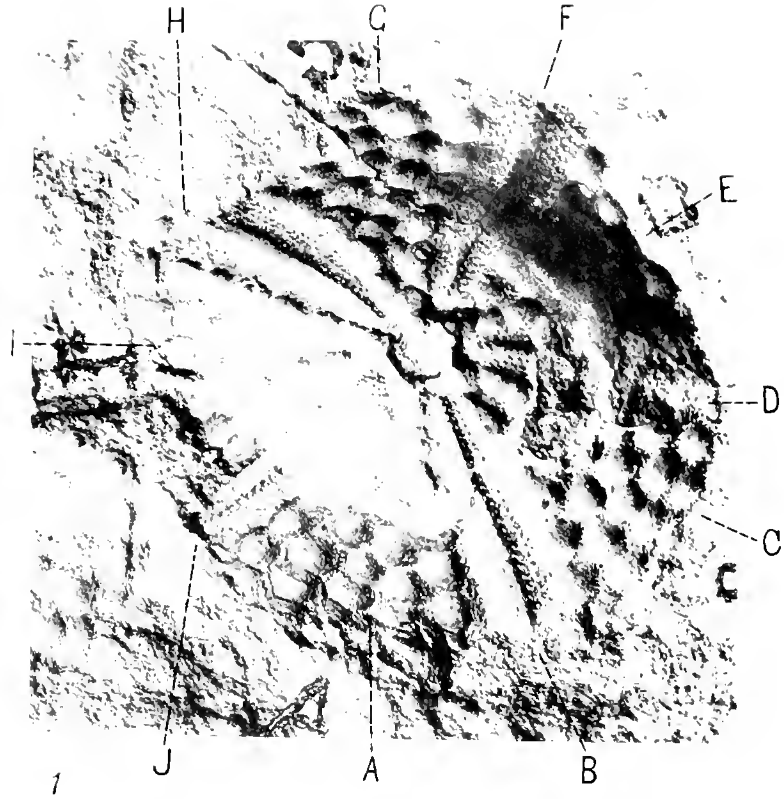

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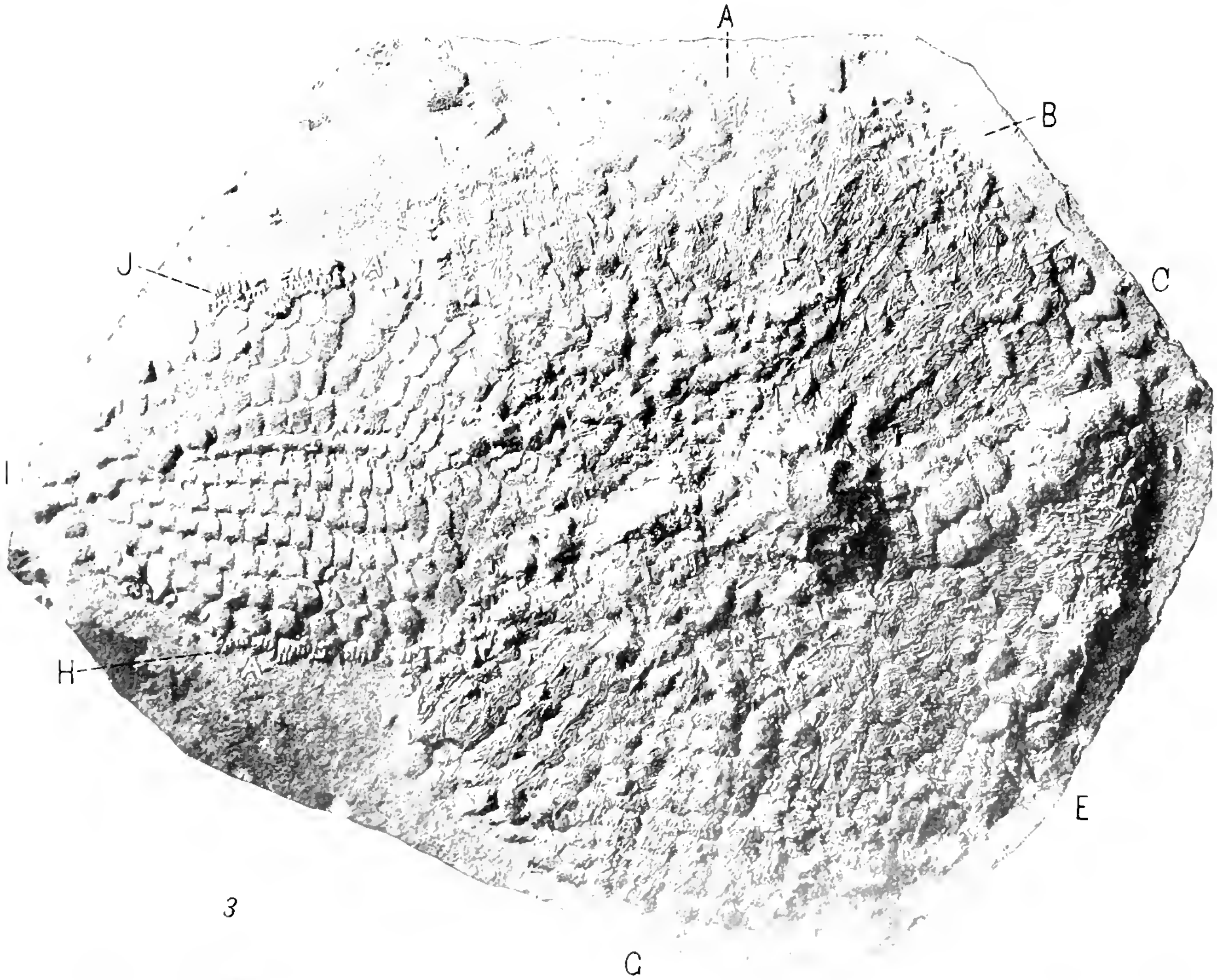

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PLATE 66.

Lepidesthes wortheni Jackson. Page 416.

Figs. 1, 2. Keokuk Group, Lower Carboniferous, Crawfordsville, Indiana.

Fig. 1. F. Braun Coll. An exceptionally clear specimen. Natural size. Eight columns of regular hexagonal plates in each ambulacral area, pore-pairs in the upper part of each plate, toward the next adjacent interambulacrum in each half-area. Three columns of plates at the mid-zone in each interambulacrum all imbricating dorsally and from the center laterally and over the ambulacrals. The median column, as usual in the species consists of wider plates which imbricate laterally in two directions, right and left, over the two adradial columns (compare *Lepidesthes colletti*, Plate 71, fig. 1; *Meekechinus elegans*, Plate 76, fig. 1). Where plates are wanting in interambulacrum A, the beveled edges show clearly. Drawing, Plate 67, fig. 8.

Fig. 2. Mus. Comp. Zoöl. Coll., 3,171 (from R. T. J. Coll.). Natural size. Specimen smaller than fig. 1. Ambulacral plates are hexagonal in form. Interambulacrum A is nearly complete; tubercles very clear. Drawing, Plate 67, fig. 10.

Fig. 3. No original label, but probably from the Keokuk Group of Crawfordsville, or that vicinity. Boston Soc. Nat. Hist. Coll., 11,601, holotype. A small individual. Natural size. Ambulacral plates are more rhombic in form than in figs. 1 and 2. Interambulacrum C shows four columns of plates ventrally as a character in development. Drawings, Plate 67, figs. 9 and 12.

Lepidesthes formosa Miller. Page 418.

Figs. 4–7. Kaskaskia Group, Lower Carboniferous, Pulaski County, Kentucky.

Fig. 4. Chicago Univ. Coll., 6,604, holotype. Natural size.

Fig. 5. Same specimen. × 1.7. Oriented by the Lovén method as the madreporite is preserved. Eight columns of plates in an ambulacral area and five columns of plates in each of the interambulacral areas at the mid-zone. Some ocular, genital, and periproctal plates are preserved. A madreporite with fine pores is clearly seen. Drawings, Plate 68, figs. 4–7.

Fig. 6. Chicago Univ. Coll., 6,604, paratype. Natural size. Another specimen although with the same catalogue number, with parts of the lantern in place. Drawings, Plate 68, figs. 8 and 9.

Fig. 7. F. Springer Coll., 8,042. Enlarged. × 2. A very complete specimen for the ventral region. Teeth and pyramids are in the oral area, with ambulacral plates alone on the peristome. Eight columns of plates in each ambulacral area and four columns of plates in each interambulacral area as far dorsally as they are preserved. Drawing, Plate 68, fig. 3.

Lepidesthes coreyi Meek and Worthen. Page 423.

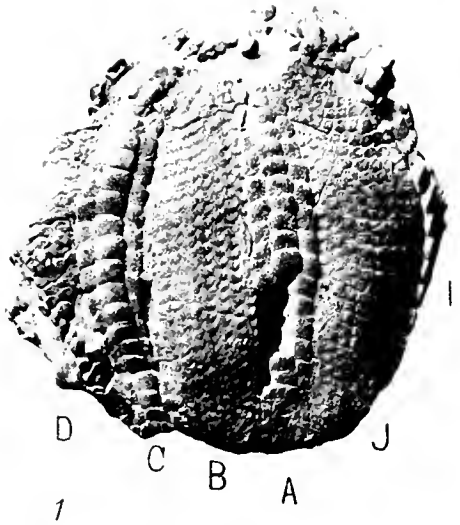
Fig. 8. Keokuk Group, Lower Carboniferous, Crawfordsville, Indiana. F. Braun Coll. Natural size. The ambitus is above the mid-zone (p. 32). There are ten to twelve columns of plates in each ambulacral area and six columns of plates in each of the interambulacral areas at the mid-zone. A very large and complete specimen. Drawings, Plate 68, figs. 18–20.

Fig. 9. Same horizon and locality. Univ. of Michigan Coll., 119, holotype. Natural size. Quite complete from the ventral border to the mid-zone, but in part wanting dorsally. Ten columns of plates in each ambulacral area and six columns of plates in each interambulacral area at the mid-zone. Interambulacral plates imbricate strongly dorsally and from the center laterally and over the ambulacra.

Fig. 10. The same specimen (after Meek and Worthen, 1873, Plate 16, fig. 2). Natural size. Outline restored dorsally as conceived by the authors; an interambulacral plate with secondary tubercles enlarged.

Lepidesthes carinata sp. nov. Page 424.

Fig. 11. Keokuk Group, Lower Carboniferous, Crawfordsville, Indiana. Mus. Comp. Zoöl. Coll., 3,175 (from R. T. J. Coll.), holotype. Natural size. Strongly elevated melon-like ambulacral areas, twelve columns of plates in an ambulacral area and six columns of plates in the interambulacral areas at the mid-zone as far as ascertained, but the details for most parts are obscure.



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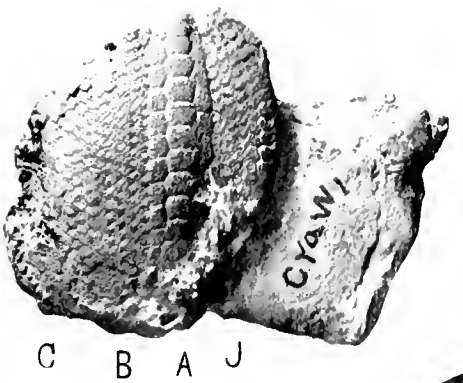

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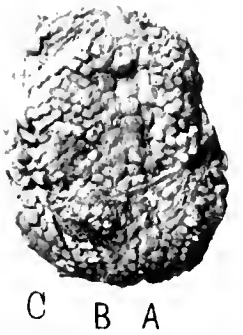

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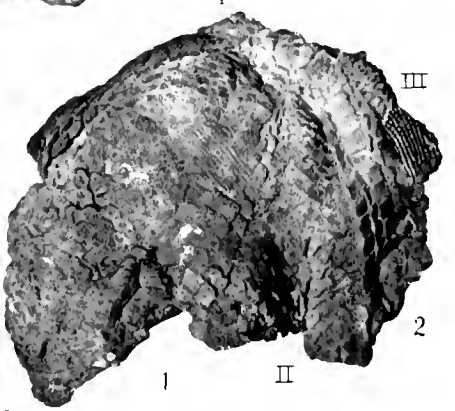

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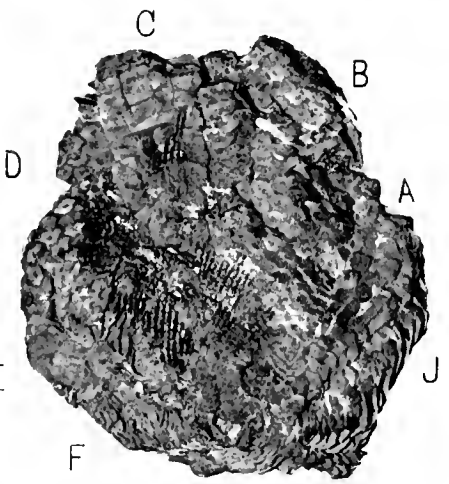

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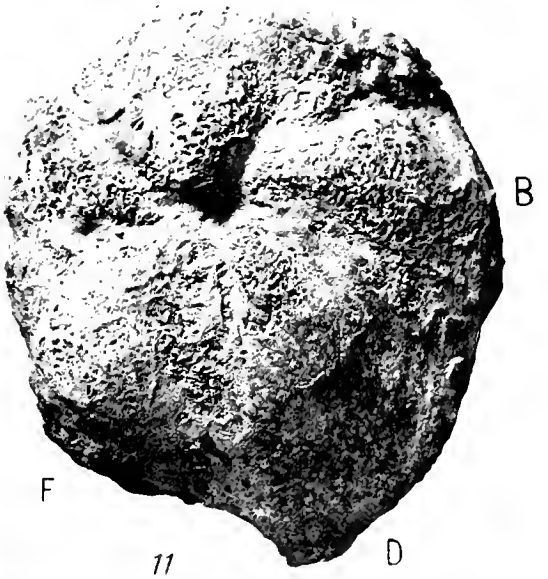

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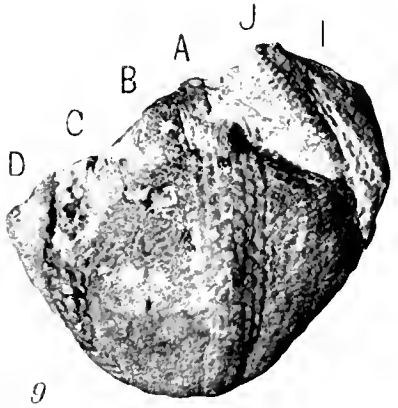

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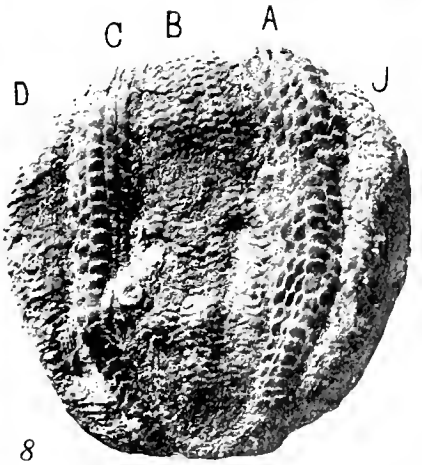

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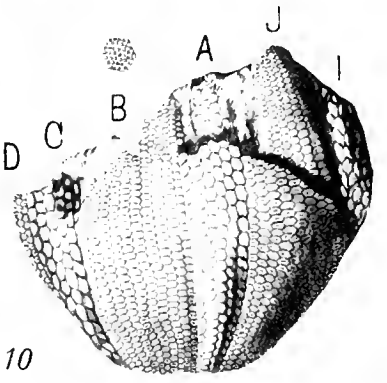

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Perischocidaris PLATE 67.

~~Perischodomus~~ harteiana (Baily). Page 408.

Figs. 1–3. Same specimen as photographs, Plate 65, figs. 1 and 2. Holotype.

Fig. 1. From near the mid-zone. Drawn from the original mold; therefore the lettering is reversed. × about 3. Three columns of ambulacral plates in a half-area.

Fig. 2. Interambulacrum drawn from a plaster cast of the original mold. × 1.1. Five columns of plates near the mid-zone; columns 5, 4, and 3 drop out dorsally.

Fig. 3. Drawn from a plaster cast of the original mold. × 1.4. Ocular insert, four genitals with three, five, or six pores each. No pores visible in genital E. Interambulacrum in contact with the oculars laterally.

Proterocidaris giganteus Koninck. Page 410.

Figs. 4–7. Lower Carboniferous, Dinant, Belgium. Drawn from Fraipont's, 1904, photographic figures of what he calls *Oligoporus sorcili* sp. nov., here considered a synonym.

Fig. 4. Segment of interambulacrum from mid-zone, seen from the exterior, adapted from Fraipont, 1904, Plate 5, fig. 1. × 0.9. There are 13 columns of interambulacral plates, the 13th originates on the left; an adjacent adradial plate, X, has six instead of five sides as is usual. Small primary with secondary tubercles.

Fig. 5. Segment of an interambulacrum and ambulacrum, a little above the mid-zone, adapted from Fraipont's, 1904, Plate 5, fig. 2 (orientation reversed from his figure). × 0.9. Internal view. Four columns of plates in an ambulacral area (in B the plates are mechanically separated in the median line); pore-pairs in the middle of half-areas. Twelve columns of interambulacral plates, the twelfth originating on the left (right as seen from exterior).

Fig. 6. Same specimen as photograph, Plate 65, fig. 3. × 0.9. From interambulacrum I to show imbrication as seen from interior; plates bevel adorally and toward the center and over plates of column 9. (Compare Plate 19, fig. 1.)

Fig. 7. The same specimen. Interambulacral plates showing small primary and secondary spines. × 1.9.

Lepidesthes wortheni Jackson. Page 416.

Figs. 8, 10, 11, 13, 14. Keokuk Group, Lower Carboniferous, Crawfordsville, Indiana.

Fig. 8. Same specimen as photograph, Plate 66, fig. 1. × 1.8. In each ambulacral area there are eight columns of regular hexagonal plates at the mid-zone; pore-pairs in the upper part of each plate nearest the next adjacent interambulacrum; occluded columns are strongly defined as the pore-pairs are in outer sides of contiguous plates. Interambulacra with three columns of plates at mid-zone. In area A there are three plates in the lowest row seen, in the next row four plates; the fourth column is represented by only four plates, above which there are three columns only. Beveling seen clearly in area A where plates are wanting; secondary tubercles only.

Fig. 9. Same specimen as photograph, Plate 66, fig. 3 (after Jackson, 1896, Plate 9, fig. 53). Holotype. × 1.8. Four columns of interambulacral plates are seen ventrally in area C and imperfectly in area A, above which there are three columns only. Ambulacral plates are more rhombic at the mid-zone than in figs. 8 and 10.

Fig. 10. Same specimen as photograph, Plate 66, fig. 2. Ambulacral detail. × 3.6. Ambulacral plates rhombic in form. Pore-pairs in peripodia in the upper left part of each plate in the left half-area and in the upper right part of each plate in the right half-area. Tubercles are similar to those of the interambulacrum.

Fig. 11. Section at the ambitus to show the beveling of plates, ambulacral plates are shaded. × 1.8.

Fig. 12. Portion of lantern from reverse side of same specimen as photograph, Plate 66, fig. 3. Holotype. × 2.5. Left and right half-pyramids, foramen magnum shallow; the left epiphysis in place, but the right epiphysis is wanting.

Fig. 13. Yale Mus. Coll., 319. Spines. × 3.

Fig. 14. The same specimen, spine enlarged. × 11. Acicular, swollen at the base, with fine vertical striae.

Lepidesthes laevis Trautschold. Page 418.

Fig. 15. Lower Carboniferous, Moscow, Russia. Museum fur Naturkunde Coll., Berlin. × 2.4. Seen from the exterior, showing four of the ambulacral and two interambulacral columns. Pore-pairs are in the upper part of plates. Interambulacral plates rounded, imbricating dorsally and laterally; a few tubercles are in place.

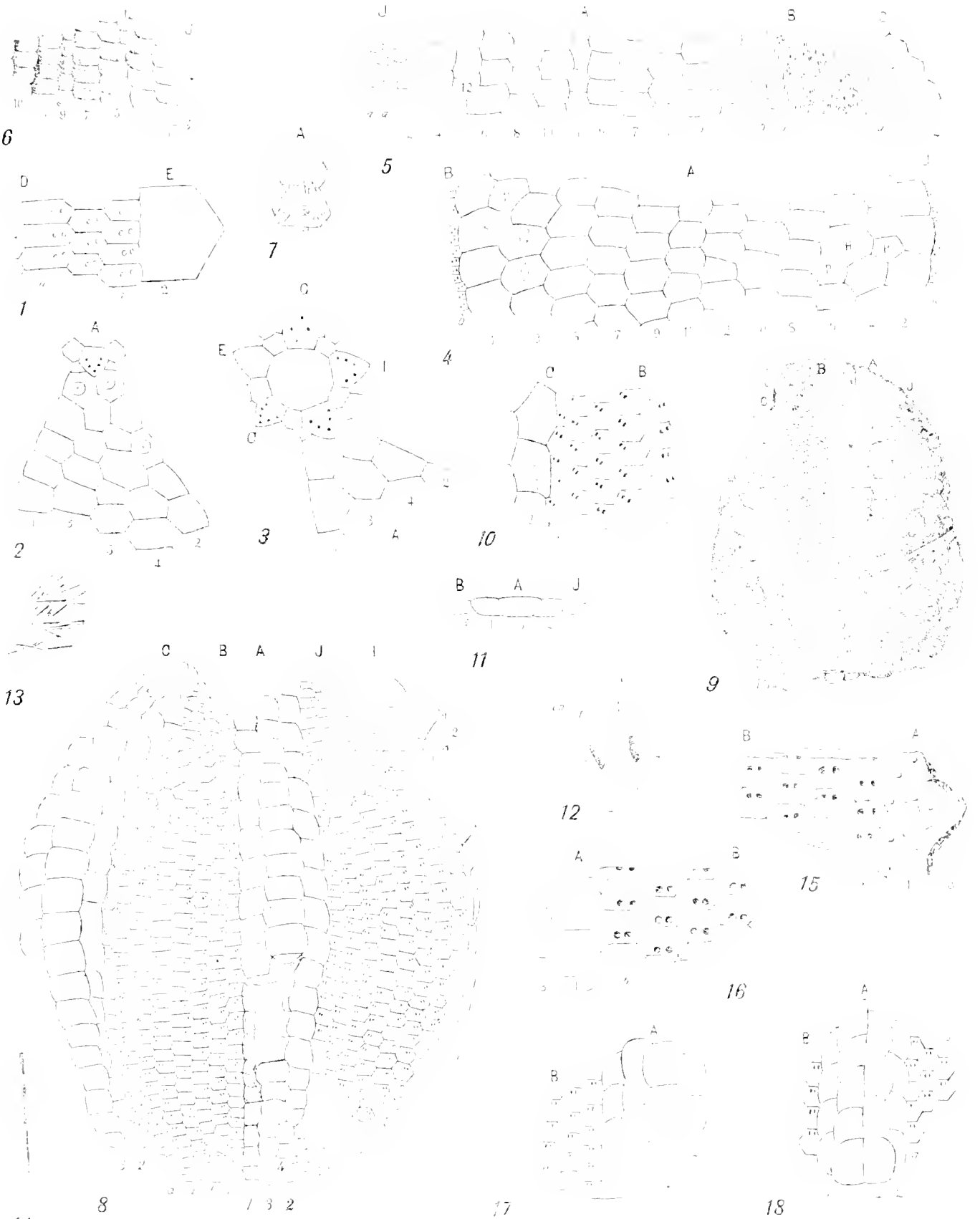
Fig. 16. Same specimen seen from the interior. × 2.4. Pore-pairs are in the lower part of plates, interambulacral plates hexagonal, not rounded as on the exterior. (Compare text-figs. 32–34, p. 75.)

Figs 17, 18. Lower Carboniferous, Miatschkowa, Province of Moscow, Russia (after Trautschold, 1879, p. 8; the orientation reversed from Trautschold's). Cotypes. Enlarged from Trautschold's original figures. × 1.7.

Fig. 17. Three of the ambulacral with four interambulacral columns. Interambulacral plates rounded, imbricating.

Fig. 18. Specimen with ambulacral plates on each side of the interambulacrum; four columns of interambulacral plates.

Fig. 9 drawn by J. H. Emerton; figs. 1–3, 15, and 16 from my sketches; figs. 4–7 from Fraipont's photographic figures, figs. 17 and 18 after Trautschold; figs. 8 and 10–14 from nature by J. Henry Blake.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Lepidesthes laevis Trautschold. Page 418.

Fig. 1. Lower Carboniferous, Moscow, Russia. Museum für Naturkunde, Berlin. × 1.2. Six columns of ambulacral plates and a section showing adoral imbrication of same.

Fig. 2. Same specimen, one ambulacral plate enlarged.

Lepidesthes formosa Miller. Page 418

Figs. 3–14. Kaskaskia Group, Lower Carboniferous, Pulaski County, Kentucky.

Fig. 3. Same specimen as photograph, Plate 66, fig 7. × 4.8. Orally teeth and pyramids are in place. Ambulacral plates only on the peristome. Four columns of ambulacral plates in area B ventrally, increasing to eight columns aborally; all imbricate ventrally. Primordial interambulacral plates in the basicoronal row, two plates in the second, three in the third, and four in the fourth row. Interambulacral plates imbricate dorsally and laterally.

Figs. 4–7. Univ. of Chicago Mus. Coll. Same specimen as photographs, Plate 66, figs 4 and 5. Holotype.

Fig. 4. Segment at the mid-zone. × 4.8. Eight columns of plates in each ambulacral area and five columns of plates in each interambulacral area.

Fig. 5. Dorsal portion of test. × 4.6. Ambulacra with one or two plates next the ocular, increasing in number passing ventrally. Interambulacral columns all extend to the apical disc, young plates being in contact with the oculars. Oculars (shaded) are all insert with two pores, a remarkable feature (pp. 89, 413). Madreporite with two genital and madreporic pores (p. 172). Genitals 1 and 5 have three pores each. Periproct with angular, thin plates.

Fig. 6. Section at mid-zone. × 4.6. To show beveling of interambulacral plates; ambulacral plates shaded.

Fig. 7. Isolated ambulacral plate, to show the dorsal and ventral bevel. × 4.6

Figs. 8, 9. Chicago Univ. Coll., 6,604. Same specimen as photograph, Plate 66, fig. 6. Paratype.

Fig. 8. Genital plate, with three pores. × 2.4.

Fig. 9. Two pyramids. × 2.3. In *b*, tooth in place, seen from exterior; in *a*, the tooth, seen from the interior, is grooved.

Figs. 10–15. Sloan's Valley, Pulaski County, Kentucky. F. Springer Coll.

Fig. 10. Springer Coll., 8,023. Pyramid, with tooth in place, restored ventrally, as indicated by dotted lines. × 2.3. Epiphyses wanting; foramen shallow. The inner aspect and section of the tooth are drawn from another specimen, which is in the Springer Coll., 8,023.

Fig. 11. Springer Coll., 8,027. Upper part of a left and right half-pyramid with epiphyses in place. × 2.2.

Fig. 12. Springer Coll., 8,033. Pyramid, in side view, with ridges for the attachment of the interpyramidal muscle and an epiphysis, showing the tubercle, *tu.*, and glenoid cavity, *gl.*, for articulation with the brace. × 1.7. (Compare Plate 2, fig. 7.)

Fig. 13. Springer Coll., 8,043. Brace, with epiphyses, the latter restored, as indicated by dotted lines. × 4.7.

Fig. 14. The same specimen, face view, showing the brace resting against the epiphysis of the right half-pyramid, but the epiphysis is wanting in the left half-pyramid. × 4.6.

Lepidesthes devonicans Whidborne. Page 420.

Figs. 15–17. Devonian, Pilton Beds, North Devon (after Whidborne, 1898, Plate 25, figs. 3a, 3b, and 3c). Museum of Practical Geology Coll., London, 7,160, and 7,161, counterparts, holotype.

Fig. 15. From a wax cast of ambulacral plates showing pore-pairs. × 3.

Fig. 16. From a wax cast of interambulacral plates, showing tubercles. × 3.

Fig. 17. Spine. × 6.

Lepidesthes coreyi Meek and Worthen. Page 423.

Figs. 18–22. Keokuk Group, Lower Carboniferous, Crawfordsville, Indiana.

Fig. 18. Same specimen as photograph, Plate 66, fig. 8. Segment at the mid-zone. × 2.3. Ten columns of plates in the ambulacral area and at this zone five columns of plates in the interambulacral area.

Fig. 19. Same specimen. × 2.2. Ambulacral plates with tubercles and spines.

Fig. 20. Same specimen. × 2.4. Interambulacral plates with tubercles and spines.

Fig. 21. Yale Mus. Coll., 317. Spines tapering, swollen at the base, longitudinally finely striate. × 4.9. From a very large specimen, about 75 mm. high.

Fig. 22. Freiburg, i. B., Museum. Enlarged. Base of the test with the lantern in place.

Figs. 1, 2, and 22 after my sketches; figs. 15–17 after Whidborne by W. M. Barrows; all others figs. by J. Henry Blake.


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PLATE 69.

Lepidesthes colletti White. Page 425.

Fig. 1. Keokuk Group, Lower Carboniferous, Montgomery County, Indiana. Mus. Comp. Zoöl. Coll., 3,178 (from R. T. J. Coll.). Enlarged × 1.6. Height of the specimen 44 mm. through the axis III, 5. A very complete specimen, oriented by the presence of the madreporite with its typical pores. There are few plates in an ambulacral area dorsally near the apical disc but they increase to sixteen columns of plates in each ambulacral area at the mid-zone. Four columns of plates in each interambulacrum; oculars, genitals, and periproctal plates in place. The apical disc is small, measuring proportionately about 16 % of the diameter of the test. Drawings, text-fig. 251, p. 428; Plate 71, fig. 1 (p. 428).

Fig. 2. Keokuk Group, Lower Carboniferous, Salem, Washington County, Indiana. Univ. of Chicago Coll., 6,340. This is the specimen figured by White, 1880a, Plate 40, figs. 2, 2a. Natural size. A small specimen, but it shows sixteen columns of plates in an ambulacral area above the mid-zone and four columns of plates in an interambulacral area (p. 428).

Fig. 3. The same specimen, enlarged. × nearly 1.8.

Fig. 4. Keokuk Group, Lower Carboniferous, Bono, Indiana. Univ. of Chicago Coll., 6,641. Natural size. Not distorted, and showing the typical elliptical form of this species, sixteen columns of plates in an ambulacral area and four columns of plates in each interambulacral area at the mid-zone. Ambulacral Plates are narrow hexagons at the mid-zone. Drawing, Plate 70, fig. 2 (p. 428).

Fig. 5. Keokuk Group, Lower Carboniferous, Montgomery County, Indiana. F. Braun Coll. Natural size. Small specimen partly embedded in the rock, very well preserved, shows periproctal plates dorsally. There are sixteen columns of plates in an ambulacral area and four columns of plates in each interambulacral area (p. 429).

Fig. 6. Keokuk Group, Lower Carboniferous, Montgomery County, Indiana. Mus. Comp. Zoöl. Coll., 3,177 (from R. T. J. Coll.). Natural size. Specimen uncompressed, of natural shape; teeth are seen ventrally; details of the coronal plates are very complete, especially at the mid-zone and dorsally. Ambulacral plates at the mid-zone are rhombic in outline, whereas in the larger specimens, figs. 7 and 8, they are hexagonal in outline at the mid-zone. Drawing, Plate 70, fig. 1 (p. 429).

Fig. 7. Keokuk Group, Lower Carboniferous, Montgomery County, Indiana. Mus. Comp. Zoöl. Coll., 3,176 (from R. T. J. Coll.). Enlarged × about 1.3. The specimen is very large, measuring 70 mm. in height. Details of the plates are very clear. Sixteen columns of plates in an ambulacral area and four columns of plates in an interambulacral area at the mid-zone, but in area A a fifth column is introduced 14 mm. below top of the specimen, the only case of a fifth column seen in the species. This specimen shows well the low hexagonal form of ambulacral plates at the mid-zone, which is characteristic of large individuals, but dorsally the plates are rhombic in form as are all the ambulacral plates of a younger individual. Drawings, Plate 70, figs. 3 and 4 (p. 429).

Fig. 8. Keokuk Group, Lower Carboniferous, Montgomery County, Indiana. Mus. Comp. Zoöl. Coll., 3,179 (from R. T. J. Coll.). Natural size. A very large and perfect specimen measuring 70 mm. in height, details of the plates exceptionally clear. Sixteen columns of plates in an ambulacral area at the mid-zone, four columns of strongly imbricating plates in each interambulacral area. In this specimen, as well as in fig. 7, the ambulacral plates are hexagonal in form at the mid-zone, whereas in younger specimens, figs. 1–6, they are rhombic at the mid-zone. As a localized stage dorsally, however, in this large specimen the younger ambulacral plates dorsally are rhombic in form as a localized stage in development (p. 430).

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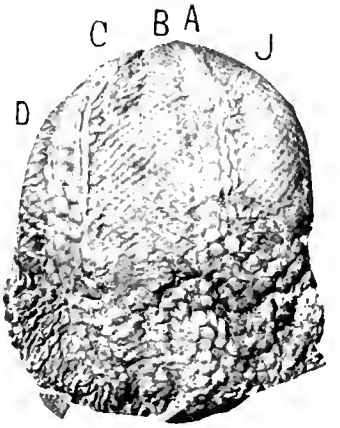

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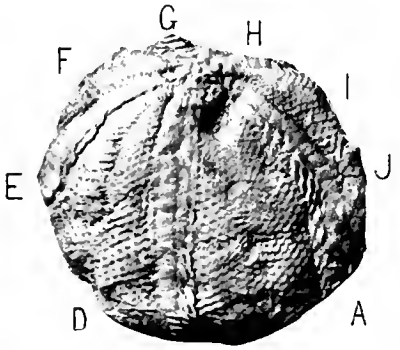

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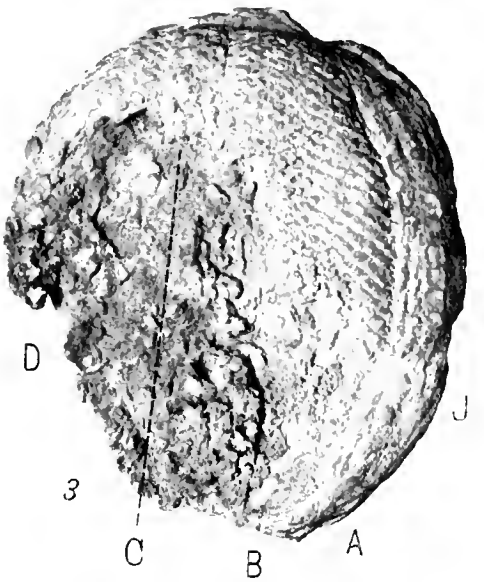

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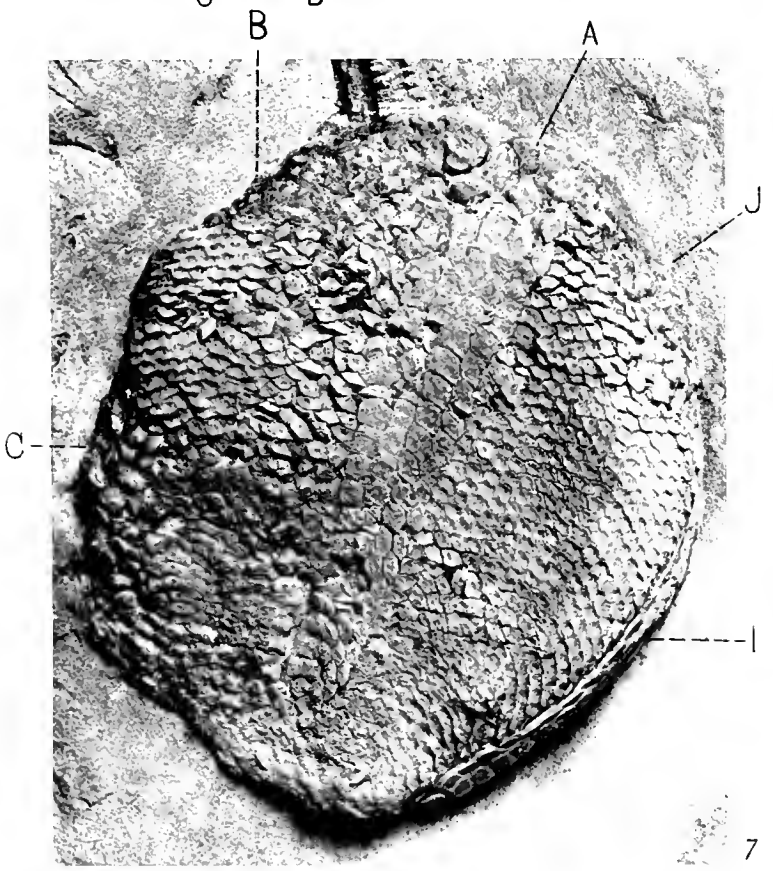

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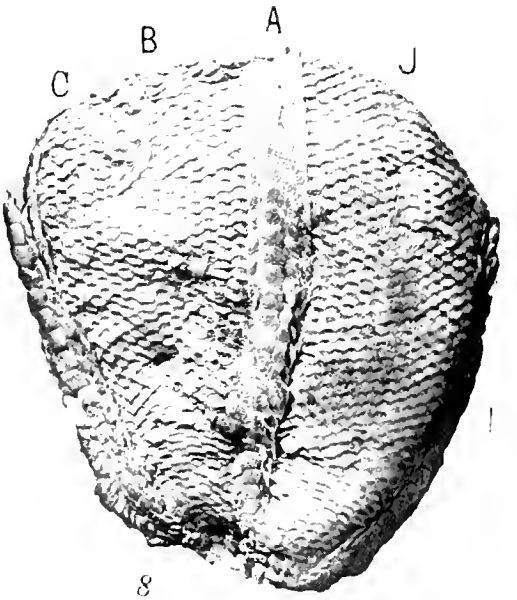

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PLATE 70.

Lepidesthes colletti White. Page 125.

Fig. 1. Same specimen as photograph, Plate 69, fig. 6. × 3.6. A specimen of the natural shape with no distortion. Ambulacral plates are nearly rhombic throughout, with sixteen columns in an ambulacral area at the mid-zone. Four columns of plates in an interambulacral area imbricating strongly dorsally and from the center laterally, and over the ambulacra on the adradial suture; the plates of column 3, that imbricates both ways laterally, are much broader than are the plates of other interambulacral columns. Ambulacral plates are rhombic in form from the mid-zone up; ventrally separated ambulacral plates show a dorsal beveled edge. Teeth are in place ventrally (pp. 426, 429). (Compare text-figs. 32–38, p. 75.)

Fig. 2. Same specimen as photograph, Plate 69, fig. 4. Segment at the mid-zone. × 3.6. Ambulacral plates are more hexagonal than in fig. 1, but the dorsal ambulacral plates in this specimen are rhombic; pore-pairs are toward the next adjacent interambulacrum in each half-area (p. 428).

Fig. 3. Same specimen as photograph, Plate 69, fig. 7. × 3.5. A very large individual; showing a segment at the mid-zone of a right half-ambulacrum, with the right occluded column, a', of the left half-ambulacrum. Ambulacral plates are strongly hexagonal in shape, being proportionately lower and wider than in small individuals (p. 429). (Compare text-figs. 14, p. 54 and 21, p. 59.)

Fig. 4. Same specimen as Plate 69, fig. 7. × 3.5. A very large individual, showing the introduction of column 5 dorsally within 14 mm. of the top of the specimen; also spines in place (pp. 426, 430).

Fig. 5. Keokuk Group, Lower Carboniferous, Montgomery County, Indiana. F. Braun Coll. A large specimen showing four columns of interambulacral plates, and tubercles (p. 429). × 3.5.

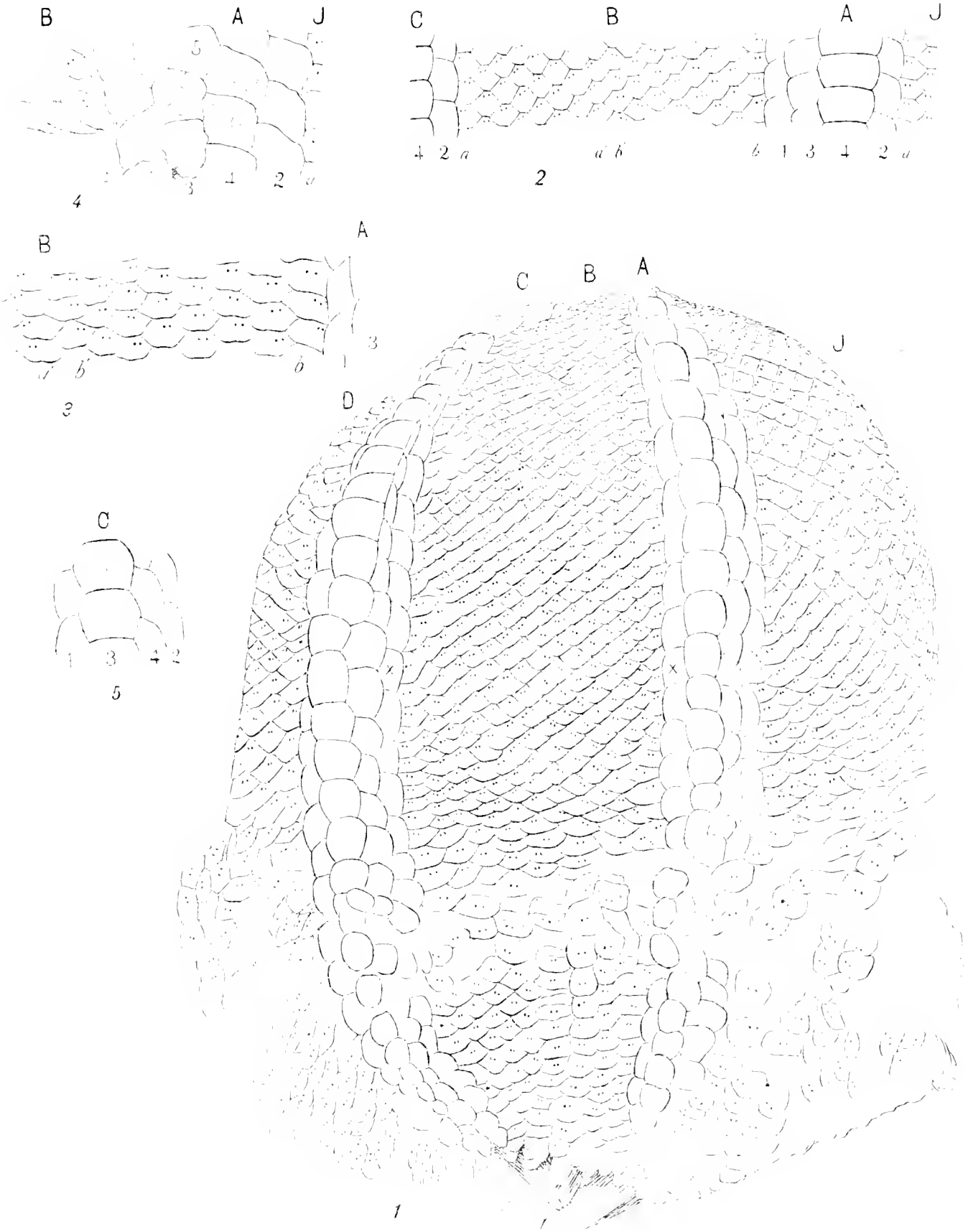

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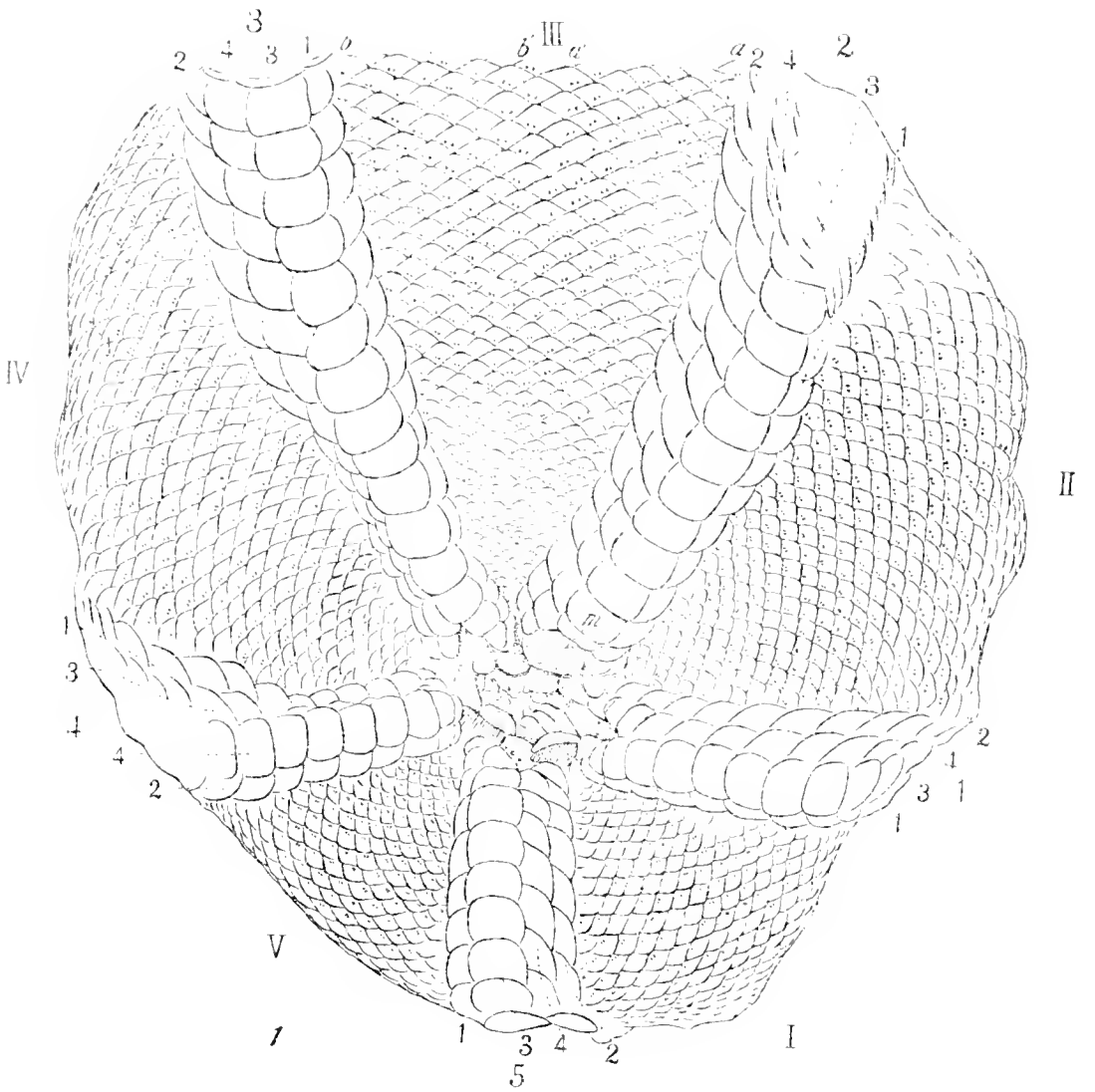
PLATE 71.

Lepidesthes colletti White. Page 425.

Fig. 1. Same specimen as photograph, Plate 69, fig. 1. × 3.4. A very completely preserved specimen, oriented by the Lovén method as the axes are known from the presence of the madreporite. Sixteen columns of ambulacral plates at the mid-zone as seen best in area III. Ambulacral plates are all nearly or quite rhombic in form as are the younger plates dorsally in very large specimens in which they are hexagonal at the mid-zone (Plate 69, fig. 7). There are but few ambulacral plates in a row in each area dorsally near the oculars, the number in the rows increasing passing ventrally to the full number at or near the mid-zone. Four columns of plates in each interambulacral area, strongly imbricating dorsally and from the center laterally and over the ambulacrals. In areas 1, 2, 3, and 5, column 3 has the wider plates which imbricate laterally in two directions; but in area 4, column 4 has the wider plates. (See also Plate 69, fig. 4; Plate 70, figs. 1 and 2.) Dorsally, four oculars are in place, which are indicated by cross lines; adorally they cover the ambulacra and laterally the interambulacra in part on either side. Five genitals are in place; genital 5 has three pores, genital 1 has two pores, and genital 2 shows fine madreporic pores, but no genital pores; probably they are hidden under the adjacent plates, genitals 3 and 4 are partially hidden and do not show any pores. Periproctal plates are thin, rounded, and rather scaly. This dorsal area is shown more enlarged in text-fig. 251, p. 428 (pp. 31, 172, 174, 427, 428).

Lepidesthes extremis sp. nov. Page 430.

Fig. 2. Same specimen as photograph, Plate 72, fig. 1. Holotype. × 1.7. Internal siliceous mold of the ventral side so that the ambulacral pores are on the lower part of each plate. (Compare Plate 67, figs. 15 and 16, where in *Lepidesthes laevis* the same ambulacral plates are seen in external and internal views.) There are sixteen columns of plates in an ambulacral area near the mid-zone, as seen in areas B and H, but there are fewer columns of ambulacral plates in an area farther ventrally. There are four columns of plates in the four interambulacra preserved, and the same number is given in area E, which is restored as indicated by dotted lines. An impression of a powerful lantern exists ventrally. Dorsal view of part of the same specimen, text-fig. 252, p. 431.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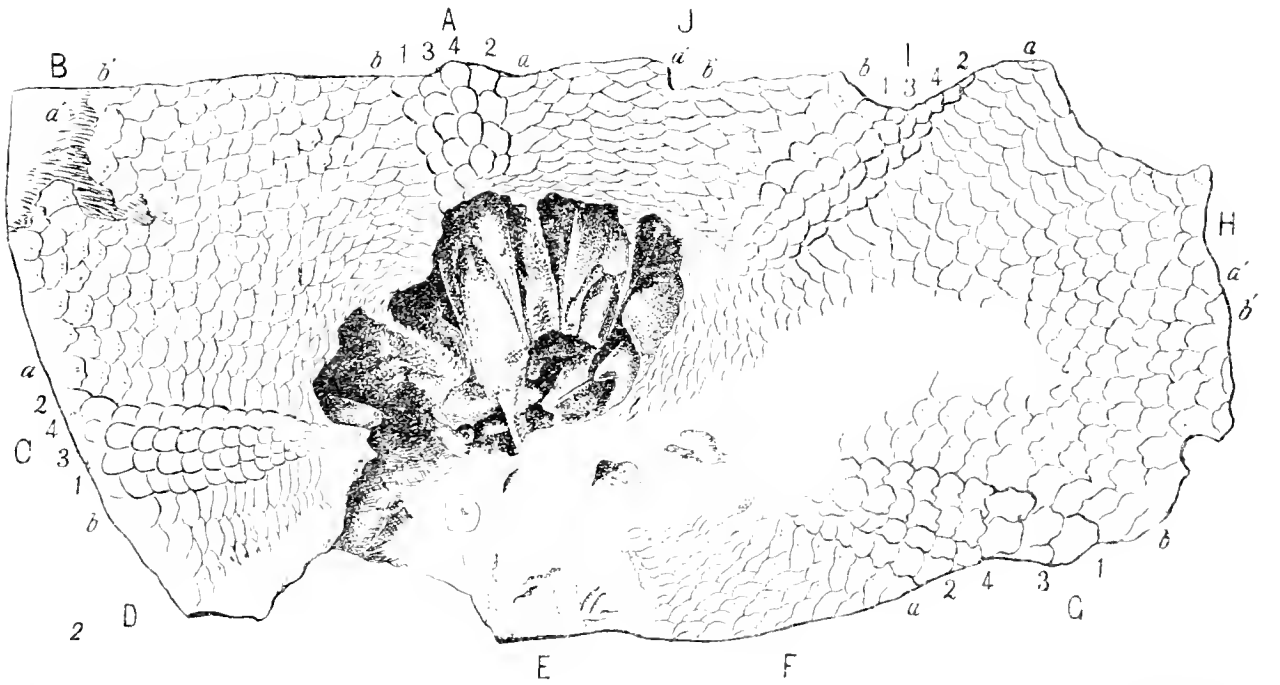
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PLATE 72.

Lepidesthes extremis sp. nov. Page 430.

Fig. 1. Putnam Hill Limestone, Carboniferous (Coal Measures), New Lexington, Perry County, Ohio, collected by Mr. Eber Hyde, who loaned the specimen, which is no. 524 of his collection. Holotype. Natural size. Internal siliceous mold of the ventral side. A large powerful species with 16 columns of plates in an ambulacral area at the mid-zone and four columns of plates in each interambulacral area; an impression of a powerful lantern ventrally. The largest and geologically the highest species of the genus. Drawing, Plate 71, fig. 2.

Fig. 2. The same specimen, dorsal view, internal mold. Natural size. In area G are seen impressions of four columns of interambulacral plates between the ambulacral areas F and H. Pores in the ambulacral plates are marked by elevated siliceous plugs. Drawing, text-fig. 252, p. 431.

Lepidesthes caledonica sp. nov. Page 432.

Figs. 3–10. Lower Carboniferous Limestone, Roscobie, Fifeshire, Scotland. All in the British Mus. Coll.

Fig. 3. British Mus. Coll., E 10,710, holotype. Ambulacral plate, from a right column next to an interambulacrum as indicated by the beveling on the right, oriented by the dorsal bevel which is strongly marked. The pore-pair is in a faint peripodium, and secondary tubercles exist. × 10.

Fig. 4. Holotype, E 10,710. Another ambulacral plate, similar to fig. 3. × 10.

Fig. 5. Holotype, E 10,710. Interambulacral plate, showing beveling ventrally and secondary tubercles. × 10.

Fig. 6. Paratype, E 10,711. Another interambulacral plate, similar to fig. 5. × 10.

Fig. 7. Holotype, E 10,710. Spines. × 20. They are tapering, swollen at the base, and longitudinally finely striate.

Fig. 8. Paratype, E 10,712. Pyramid. × 3. The pyramid is wide-angled, foramen magnum shallow, median suture plain.

Fig. 9. Same specimen seen from within, part of a grooved tooth in place. × 3.

Fig. 10. Paratype, E 10,704. Another pyramid, side view, faintly showing ridges for the attachment of interpyramidal muscles. × 3.

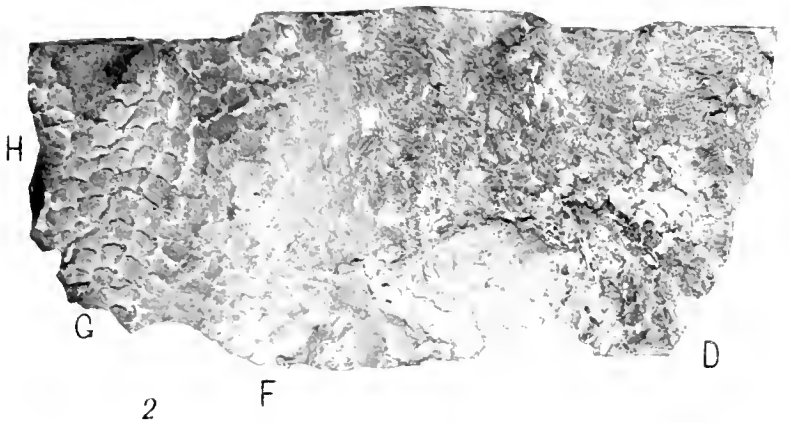
Pholidocidaris tenuis Tornquist. Page 440.

Fig. 11. Lower Carboniferous Limestone, Coplaw, Clitheroe, Lancashire. Museum of Practical Geology Coll., London, 16,304. × 2. Large, rounded, strongly imbricating interambulacral plates with eccentric primary, and secondary tubercles. A small ambulacral plate on the left is partially hidden, and there is a large plate in the center of the figure, which is apparently an ambulacral, with two pores (possibly these supposed pores are mechanically worn pits in an interambulacral plate).

Melonechinus multiporus (Norwood and Owen). Page 375.

Fig. 12. Upper St. Louis Limestone, Lower Carboniferous, St. Louis, Missouri. F. Springer Coll., 8,117 (from G. Hambach Coll., H 14). Described as the holotype of *Melonites irregularis* Hambach, here considered a synonym. Natural size. Very imperfectly preserved. Ten columns of plates in an ambulacrum at the mid-zone. In the interambulacra there are seven columns of plates at the mid-zone in three areas; the other interambulacral areas are only preserved ventrally where there are five columns as usual in most species of the genus at that area (p. 380). The orientation is reversed from that given by Hambach.

Figs. 1, 2, and 12 from photographs by F. A. Saunderson; figs. 3–11 drawn by G. C. Chubb.



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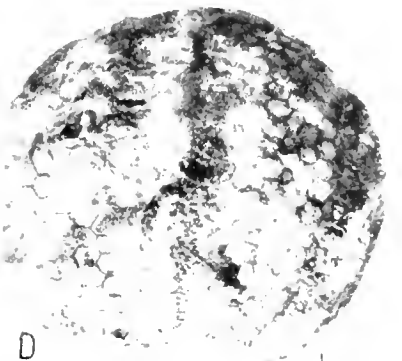

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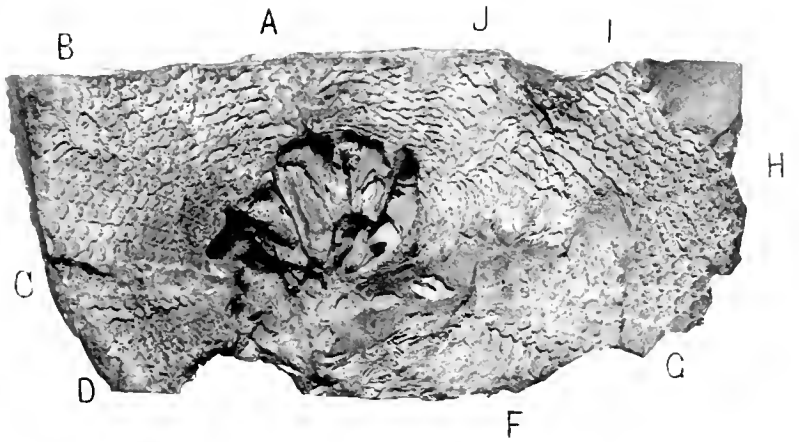

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PLATE 73.

Lepidesthes extremis sp. nov. Page 430.

Figs. 1, 2. Putnam Hill Limestone, Carboniferous (Coal Measures), New Lexington, Perry County, Ohio, collected by Eber Hyde, who loaned the specimen, which is no. 525 of his collection. Paratype. Siliceous external molds.

Fig. 1. Interambulacral plates, rounded in outline with secondary tubercles occurring as pits in the matrix. × 5.3.

Fig. 2. Spines, slender and tapering. × 5.3.

Pholidocidaris irregularis (Meek and Worthen). Page 434.

Fig. 3. Same specimen as photograph, Plate 75, fig. 1. × 1.8. Dorsal view, a fine delicately built test; apparently with six columns of plates in an ambulacral area, as indicated by three columns of plates in the right half of area D. The ambulacral plates are all small. There are six columns of plates in each of the two interambulacral areas preserved; columns 5 or 6 drops out early passing dorsally. Of the interambulacra, the adambulacral plates are much the largest, each with a large eccentric perforate primary tubercle and secondary tubercles. The plates of the middle columns of the interambulacra have secondary tubercles only; all interambulacral plates are thin, scaly, rounded in outline and imbricating strongly dorsally and from the center laterally and over the ambulacrals. A genital plate in area A has ten genital pores, and next to it a small plate, probably an ocular, has two pores (p. 137).

Fig. 4. Same specimen as photograph, Plate 75, fig. 2. × 1.8. A very similar specimen to fig. 3. In interambulacral area A, there are six columns, while in C there are only five columns of interambulacral plates, and in G there are apparently only five, but in area I there are again six columns of plates. Two genital plates have numerous pores each. Ambulacral plates are all small (p. 436).

Fig. 5. The same specimen, a small primary and a secondary spine. × 1.8 (p. 435).

Fig. 6. Keokuk Group, Lower Carboniferous, Warsaw, Illinois. Mus. Comp Zoöl. Coll., 3,070. This is the holotype of *Pholidocidaris miceki* Jackson, here considered a synonym. × 0.9. Ventral area, the only known specimen of the genus showing this area at all satisfactorily. Ambulacral plates are large, each with a central pore-pair. There are apparently six columns of ambulacral plates at the mid-zone in an area. In interambulacrum C the primordial interambulacral plate is in place in the basicoronal row; there are two plates in the second row and three in the third. The fourth column does not originate until the sixth row, which is exceptionally late for any Palaeozoic species; the fifth column originates in the seventh row and the sixth column in the eighth row. Interambulacrum A is confused and imperfectly preserved. There is a primary tubercle on all interambulacral plates ventrally, whereas dorsally (figs. 3, 4) primary tubercles occur only on adradial plates (p. 438).

Fig. 7. The same specimen, from the area marked X in area C of fig. 1. × 1.8. Ambulacral plates showing their relatively large size, ventral imbrication, central pore-pair in an elevated prominence, and interambulacral plates, which are scaly, rounded, imbricating dorsally and laterally (p. 438).

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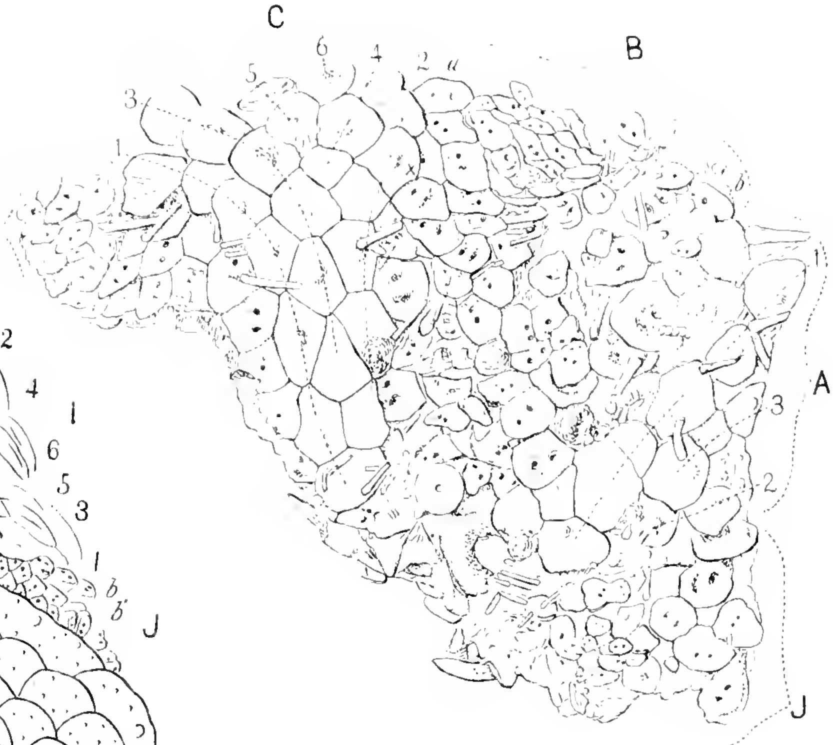

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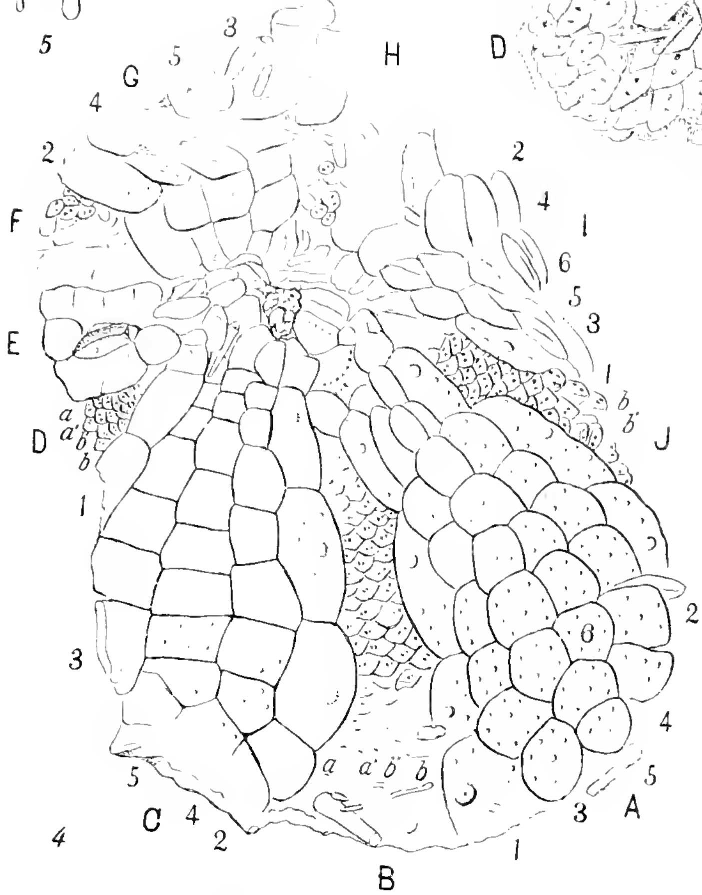

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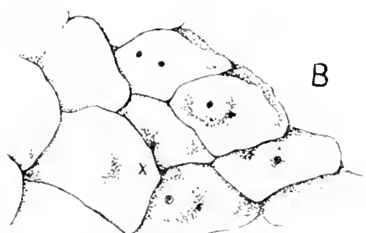

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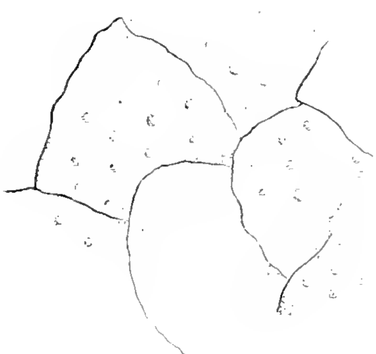

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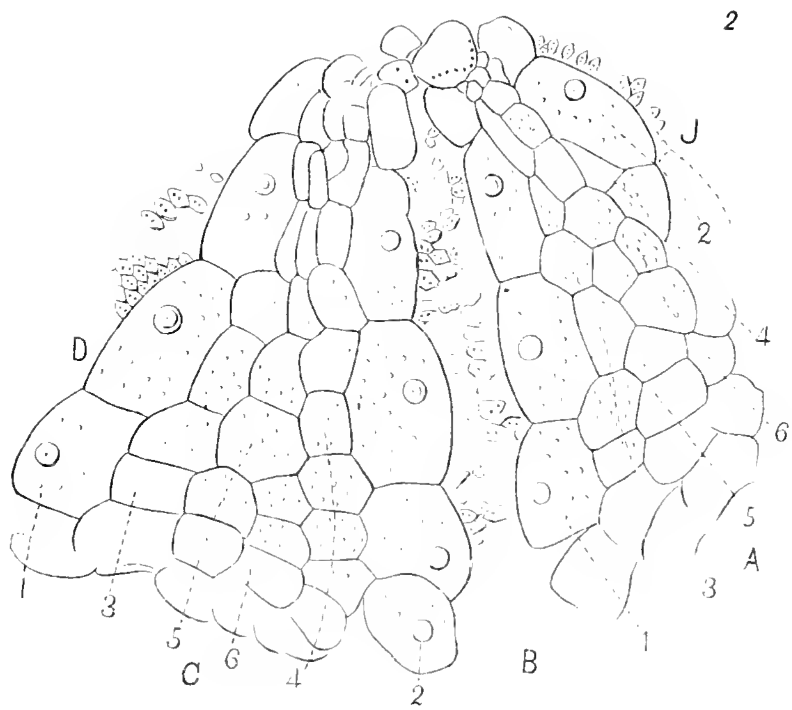

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PLATE 74.

Pholidocidaris irregularis (Meek and Worthen). Page 434.

Fig. 1. Keokuk Group, Lower Carboniferous, Montgomery County, Indiana. F. Braun Coll. × 1.8. This specimen, while imperfect and fragmentary, is most instructive. It represents a radial segment of a test flattened and distorted; also part of the dorsal plates have been removed. As a result, we see the exterior of part of the plates of the dorsal area (unshaded) and the interior of a portion of the ventral area (shaded for contrast); also a fragment of the lantern. Ambulacral plates ventrally (shaded) are very large, about rhombic in form, with pore-pairs about in the middle of each plate. On the other hand, ambulacral plates dorsally are small, and judging from the lower part of area B, there are six columns in an area at the ambitus. The interambulacra are represented clearly only by dorsal plates, column 1 of area A, column 2 of area C, and columns 2, 4, and 6 of area E (compare Plate 73, fig. 3). The adambulacral plates are striking, much larger than those of the median columns, scale-like, rounded, imbricating strongly; each adambulacral plate bears a primary eccentric perforate tubercle, whereas there are no primary tubercles on the plates of median columns. Two genital plates, *g*, have each numerous pores. A fragment of the lantern shows imperfectly a brace, *b*, two epiphyses, *ep.*, and part of a pyramid, *p* (p. 439).

Fig. 2. Keokuk Group, Lower Carboniferous, Keokuk, Iowa. F. Springer Coll., 8,015. × 0.9. This specimen, like the last, is very fragmentary, showing part of the dorsal plates (not shaded), part of the ventral plates (shaded to differentiate them), and an imperfectly preserved lantern. The specimen when alive was probably 100 mm. or more in diameter. Ambulacral plates are confused and imperfect, the most obvious feature being that the dorsal plates are small, as in fig. 1. The ventral (shaded) interambulacral plates imbricate toward the center of the area, and adorally; this is because they are seen from the interior. The dorsal plates (unshaded) clearly imbricate dorsally and from the center outward (compare text-figs. 32–38, p. 75). Adambulacral plates bear each an eccentric perforate primary tubercle and they are much larger than are the plates of median interambulacral columns. Six columns of interambulacral plates can be made out with reasonable certainty in area E and with less clearness in other areas. The lantern is strongly inclined, as indicated by the angles of the teeth (compare Plate 27, fig. 5); the pyramids, *p*, are in place, also the teeth, *t*, and in three areas, D, F, and H, a small worn plate that is apparently the brace. Below the letters D and F primary spines occur (p. 440).

Figs. 3–7. Keokuk Limestone, Lower Carboniferous, near Burlington, Iowa. Univ. of Michigan Coll., 1,740, C. A. White, collector. × 1.8 (p. 438).

Fig. 3. Adambulacral plate from column 1 (left side), showing an eccentric perforate primary tubercle with scrobicule and secondary tubercles; the plate is rounded, scale-like in form, with lateral and ventral beveling and facets for articulation with neighboring plates.

Fig. 4. Adambulacral plate from column 2 (right side), otherwise similar to fig. 3.

Fig. 5. Small adambulacral plate from column 1 (left side), similar to fig. 1; probably from near the mid-zone.

Fig. 6. Right half-pyramid; showing a moderately deep foramen magnum and a suture for the epiphysis.

Fig. 7. Left half-pyramid seen from within, showing pyramidal suture, dental slide, moderately deep foramen, and a wide lateral wing.

Pholidocidaris sp. Page 440.

Figs. 8–10. Kaskaskia Group, Lower Carboniferous, Pulaski County, Kentucky. F. Springer Coll., 8,047. × 5.4. A small species or a young individual, of interest only from its occurrence in the horizon and locality.

Figs. 8, 9. Two ventral ambulacral plates; 8 seen from the exterior, and 9 from the interior.

Fig. 10. Genital plates, each with many pores.

Pholidocidaris acuaria (Whidborne). Page 441.

Fig. 11. Upper Devonian, East of Barnstaple, England (after Whidborne, 1898, Plate 25, fig. 1b, the type of his genus Protocidaris, here considered a synonym of Pholidocidaris). Museum of Practical Geology Coll., London, 7,158, cotype. × 4.5. Interambulacral plates rounded, thin and scaly, with eccentric perforate primary and secondary tubercles; primary and secondary spines in place.

Pholidocidaris tenuis Tornquist. Page 440.

Figs. 12, 13. Lower Carboniferous, Hunsrücken, Germany (after Tornquist, 1897, Plate 21, figs. 8 and 9, Plate 22, fig. 8). Cotypes.

Fig. 12. Interambulacral plate. × 0.9; and enlarged × 5.4. With an eccentric perforate primary and secondary tubercles.

Fig. 13. Spine. × 1.4.

Figs. 11–13 copied by W. M. Barrows; all others drawn by J. Henry Blake.

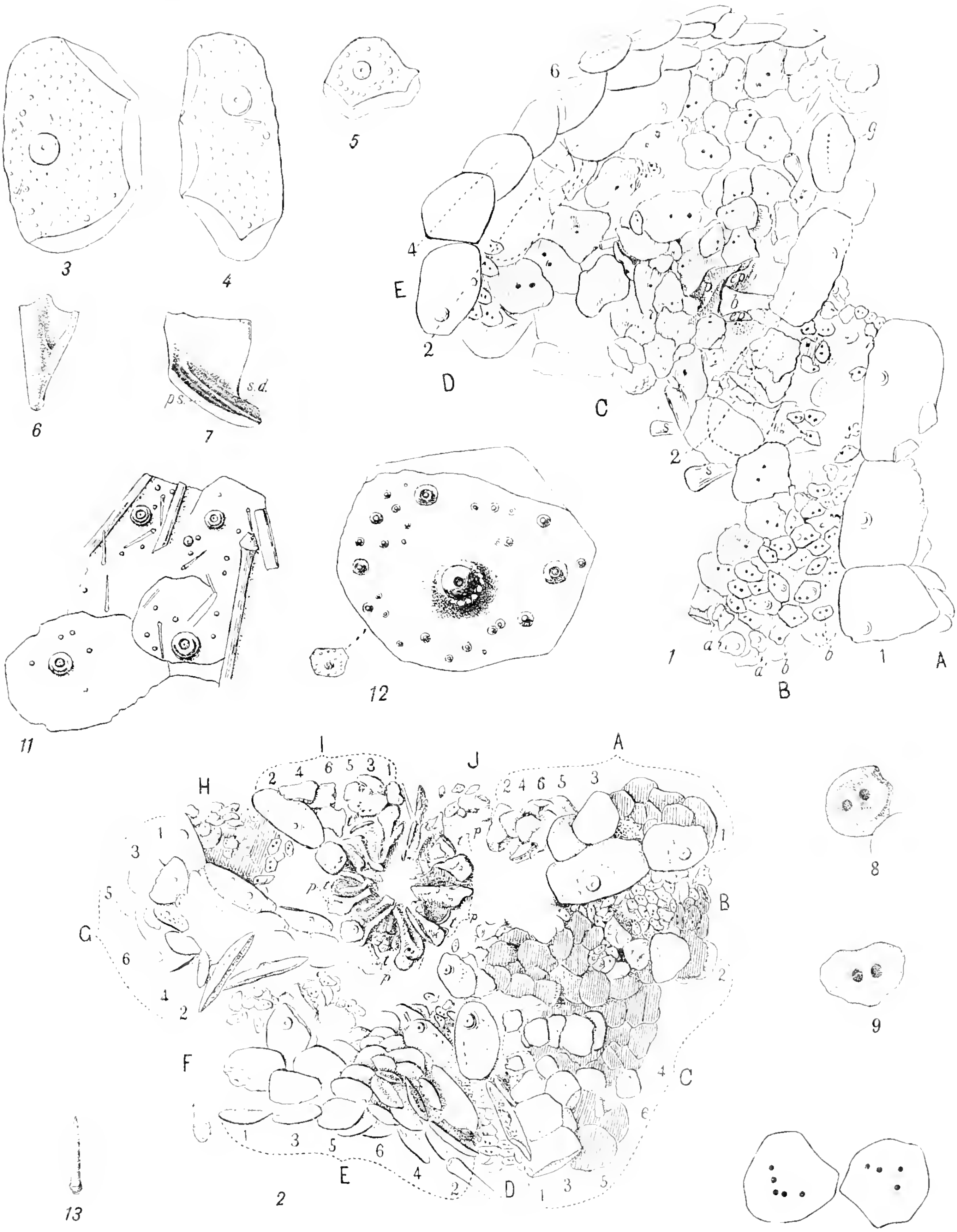
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PLATE 75.

Pholidocidaris irregularis Meek and Worthen. Page 431.

Fig. 1. Keokuk Group, Lower Carboniferous, Keokuk, Iowa. F. Springer Coll., 8,017, young individual. Natural size. Six columns of plates in an ambulacral area and six columns of plates in each interambulacral area. The plates of the adambulacral columns are relatively very large, especially high; a genital plate occurs in area A (p. 437). Drawing, Plate 73, fig 3.

Fig. 2. Keokuk Group, Lower Carboniferous, Montgomery County, Indiana. F. Braun Coll. Another young individual. Natural size. Six columns of interambulacral plates in area A, five columns in area C; there are two genital plates dorsally (p. 436). Drawing, Plate 73, figs. 4 and 5.

Figs. 3–5. Keokuk Group, Lower Carboniferous, Hamilton or Nauvoo, Illinois (after Meek and Worthen, 1873, Plate 15, figs. 9a, 9b, and 4c. Holotype (p. 436).

Fig. 3. Portion of dorsal part of a test. Natural size. The orientation is reversed from that given by Meek and Worthen. Ambulacral plates are small. Interambulacral plates imbricate dorsally and from the center laterally and over the ambulacra; in area A there is one adradial column of large, high plates, each bearing an eccentric primary and secondary tubercles, with three median columns of plates, all much smaller and lower, and bearing secondary tubercles only; the right-hand columns of this area are wanting. In area C there are plates from a right adradial and from median columns, but the plates are displaced and confused. Minute plate-like bodies scattered in the ambulacral and interambulacral areas are apparently foreign matter.

Fig. 4. Reverse side of the same specimen. Natural size. The ventral area, showing relatively large ambulacral plates with central pore-pairs, and relatively small interambulacral plates, with primary and secondary spines, all confusedly mixed.

Fig. 5. One of the primary spines, restored as indicated in outline. × about 2

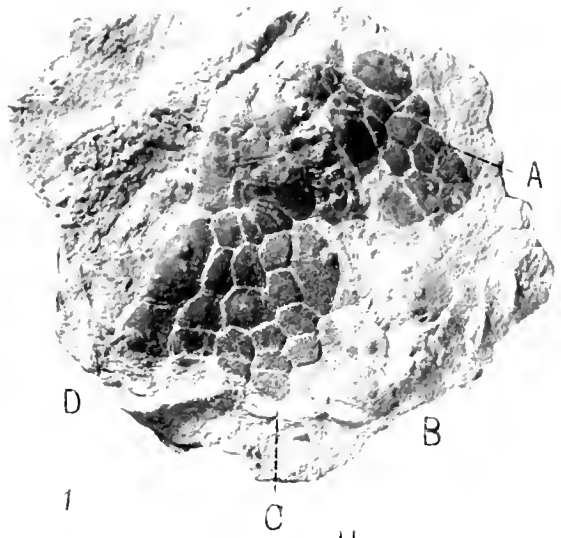
Meekechinus elegans sp. nov. Page, 443.

Figs. 6–8. Eskridge Shales, at the base of the Permian, Grand Summit, Kansas. J. W. Beede, collector, Univ. of Kansas Coll.

Fig. 6. Holotype. Natural size. The madreporite is in place so that the specimen is oriented by the Lovén system. There are 20 columns of low rhombic plates in an ambulacral area at the mid-zone, the highest number known in any sea-urchin. The number of columns in an area is progressively less as we pass dorsally to the apical disc. The interambulacra are narrow, composed in each area of three columns of similar, small, strongly imbricating plates, each typically with one small primary tubercle bounded by a scrobicule, and in addition, rather large secondary tubercles; two or more oculars and five genitals are in place, the latter each with two or more genital pores. The madreporite is very distinct with many fine pores. Drawings, Plate 76, figs. 1–4, and 6.

Fig. 7. Another specimen, paratype, almost exactly like fig. 1, but not quite as perfectly preserved. Natural size. Partially worn away dorsally so that parts of the dorsal portion of eight of the half-pyramids of the lantern are seen. Primary and secondary spines are numerous and well preserved, and in addition, tridentate pedicellariae, the first of such structures known from the Palaeozoic. Drawings, Plate 76, figs. 5, 8, and 9.

Fig. 8. A fragment of a test, paratype, with well preserved lantern; plates and spines well preserved. Natural size. Drawings, Plate 76, fig. 7.



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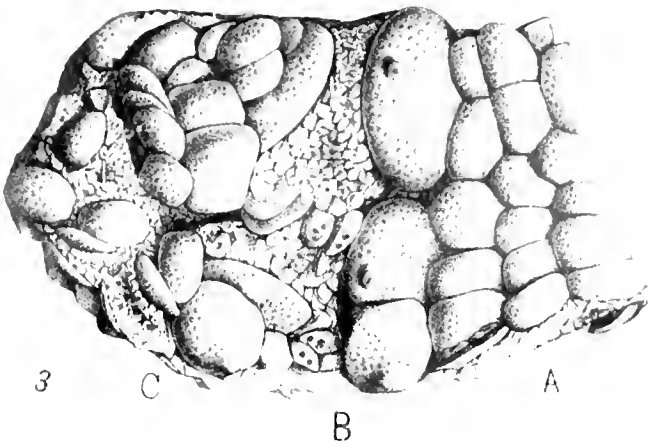

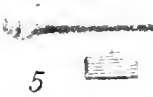

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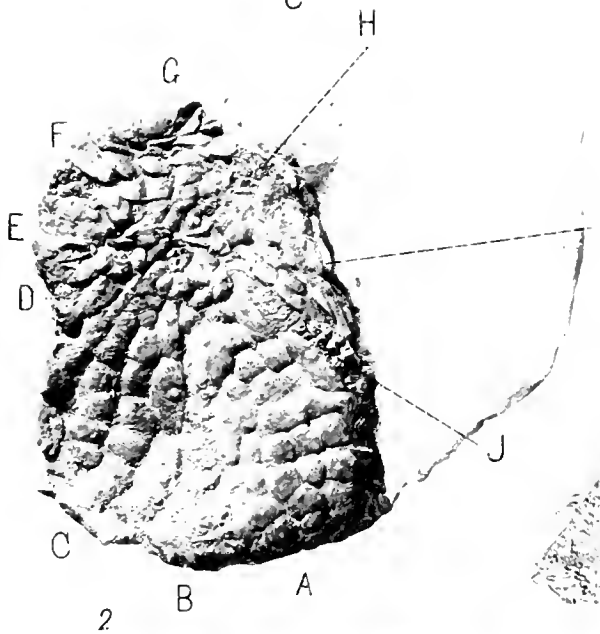

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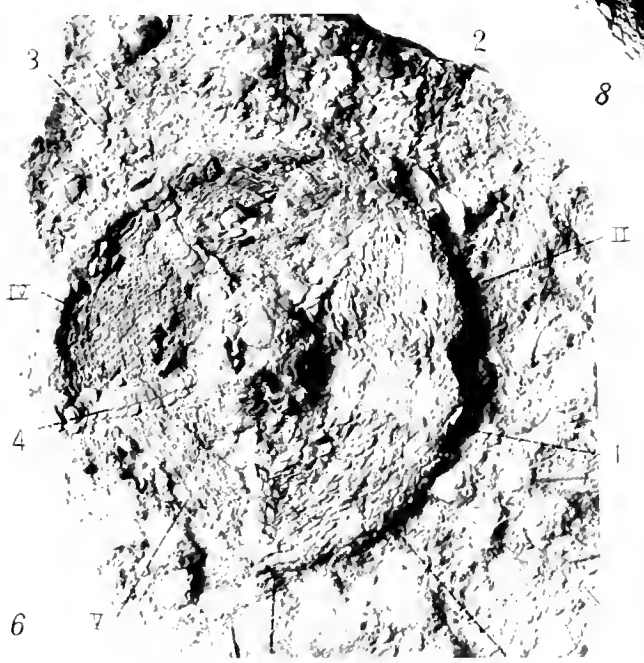

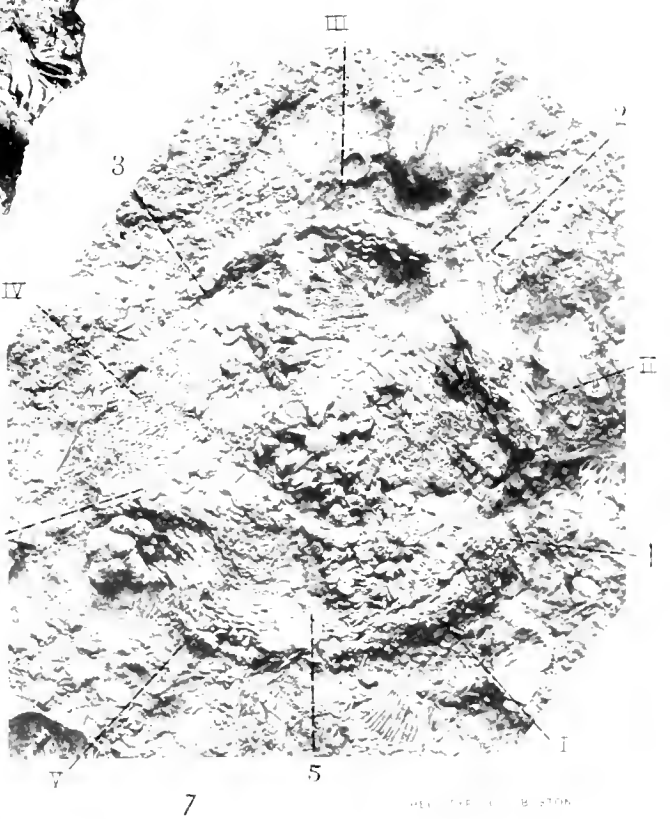

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Meekechinus elegans sp. nov.

Figs. 1–1. 6. Same specimen as photograph, Plate 75, fig. 6. Holotype.

Fig. 1. Dorsal view of the test of this remarkable echinoid. × 2.7. Ambulacra very broad, with 20 columns of plates in each area near the mid-zone, seen best in the right half of area IV, where ten plates may be counted from the center outward in a half-area. Ambulacral plates are all low, wide rhombs; pore-pairs are in peripodia in that portion of each plate nearest to the next adjacent interambulacrum. Ambulacral plates imbricate strongly ventrally and laterally bevel under the adambulacrals. Interambulacra very narrow, each composed of three columns of small plates, which are uniform in size, imbricating strongly dorsally and from the center laterally and over the ambulacra on the adradial suture. Each plate typically with a small primary and secondary tubercles; occasionally and without apparent rule, a plate of the middle column may fail to develop a larger tubercle. Three small oculars and five genitals are preserved; a large madreporite with fine pores and many small tubercles is a prominent feature (more enlarged in fig. 6).

Fig. 2. Ambulacral plates from the mid-zone of area 1, from the place marked X in fig. 1, showing ventral imbrication. × 5.3. Pore-pairs are in peripodia in the left of the plate on the left of the median line and in the right portion of the plate on the right of the median line; there are small primary tubercles with a scrobicule and secondary tubercles on each plate, the only case of such a structure of ambulacral plates known in the Palaeozoic. Small primary and secondary spines are present.

Fig. 3. Similar ambulacral plates, from the right half of the mid-dorsal region of area III from the place marked X in fig. 1. × 5.4. The aboral beveled edges are very marked; two of the plates are seen from the interior, with pores in the middle of each plate instead of near the lateral border of plate, as on the exterior.

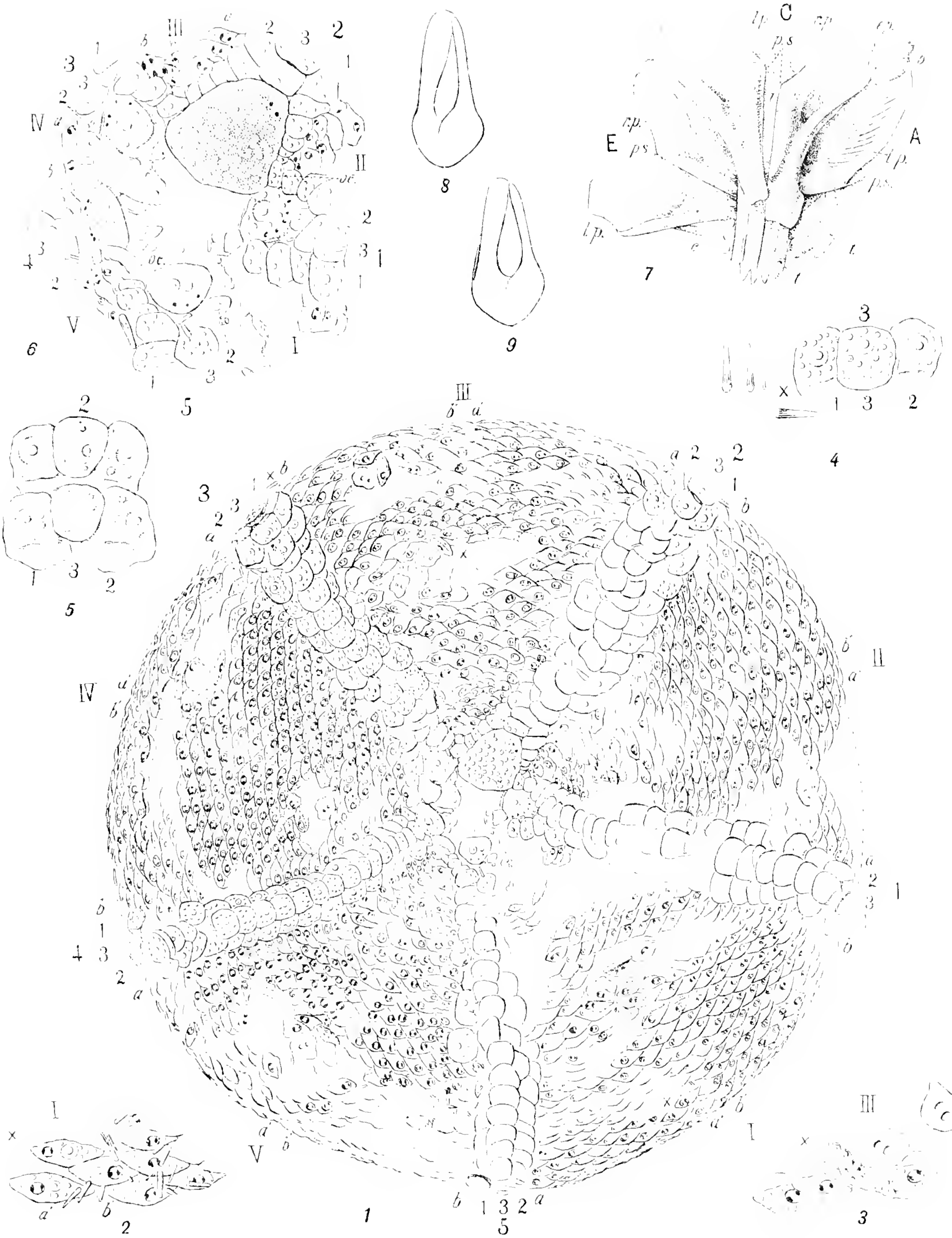
Fig. 4. Segment of an interambulacrum, at the mid-zone of area 3 from the point marked X in fig. 1. × 5.2. The plates of column 3 imbricate strongly dorsally and from the center laterally and over the ambulacrals on either side. A small perforate primary tubercle with scrobicule is in the center of each plate, with, in addition, rather large secondary tubercles. Three typical primary and a secondary spine are drawn separately.

Fig. 5. Segment of interambulacrum. Same specimen as photograph, Plate 75, fig. 7, paratype. Drawn from a point halfway between the ambitus and the apical disc in area 2. All interambulacral plates imbricate strongly dorsally and from the center laterally and over the ambulacra on the adradial suture. The middle plate of the upper row has no primary tubercle as have the others.

Fig. 6. Apical region. × 5.3. The plates in some parts are disarranged, but in others are apparently in their original relation. Oculars II and III are in place, exsert, and small, but adorally cover the ambulacra and laterally the interambulacra in part on either side. Apparently there is an ocular, *oc.*, in area V, but one cannot ascertain an ocular with assurance in areas IV or I. The madreporite is very large, with numerous fine madreporic pores, and in addition two genital pores, also many secondary, but no primary tubercles. Genitals 1, 3, and 4 are small plates each with a primary and secondary tubercles and four genital pores; genital 5 is similar, but with three pores. The ambulacra dorsally have only one plate in contact with the ocular, but the absence of a second plate is probably due to displacement during fossilization in the slipping of strongly imbricating plates. A few plates in the center may be considered as periproctal.

Fig. 7. Same specimen as photograph, Plate 75, fig. 8. Paratype. × 5.3. A nearly complete lantern. Pyramids are wide-angled, with a rather deep foramen magnum, seen best in area E. In area A the side wing of the left half-pyramid shows ridges for the attachment of the interpyramidal muscle. In area C, a tooth is in place, seen for nearly its whole length on account of the accidental separation of the half-pyramids on their suture line. The tooth is vertically striate, and distally dentate, the same structure being seen also in the tooth of area A. The left half-pyramid of area E shows the suture line for the epiphysis which is wanting, but the right half-pyramid of C has the epiphysis, *ep.*, in place, against which lies a somewhat displaced brace, *b*. A bifid compass, *c*, lies out of place below the pyramid E (p. 181).

Figs. 8, 9. The same specimen as Plate 75, fig. 7. Paratype. Tridentate pedicellariae. × 62. These are quite like the pedicellariae of modern Echini, and are the first recorded from the Palaeozoic and indeed are the first found fossil from any formation as far as I am aware excepting in the Jurassic Pelanechinus in which they are described by Groom (1887), (p. 61).



J. Henry Blake, del.